U.S. Army Center for Health Promotion and Preventive Medicine

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A PROSPECTIVE STUDY OF INJURIES AND INJURY RISK FACTORS AMONG ARMY WHEEL VEHICLE MECHANICS

U.S. Army Center for Health Promotion and Preventive Medicine
Aberdeen Proving Ground, MD

U.S. Army Research Institute of Environmental Medicine
Natick, MA

Readiness Thru Health

U.S. Army Center for Health Promotion and Preventive Medicine

The lineage of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) can be traced back over 50 years. This organization began as the U.S. Army Industrial Hygiene Laboratory, established during the industrial buildup for World War II, under the direct supervision of the Army Surgeon General. Its original location was at the Johns Hopkins School of Hygiene and Public Health. Its mission was to conduct occupational health surveys and investigations within the Department of Defense's (DOD's) industrial production base. It was staffed with three personnel and had a limited annual operating budget of three thousand dollars.

Most recently, it became internationally known as the U.S. Army Environmental Hygiene Agency (AEHA). Its mission expanded to support worldwide preventive medicine programs of the Army, DOD, and other Federal agencies as directed by the Army Medical Command or the Office of The Surgeon General, through consultations, support services, investigations, on-site visits, and training.

On 1 August 1994, AEHA was redesignated the U.S. Army Center for Health Promotion and Preventive Medicine with a provisional status and a commanding general officer. On 1 October 1995, the nonprovisional status was approved with a mission of providing preventive medicine and health promotion leadership, direction, and services for America's Army.

The organization's quest has always been one of excellence and the provision of quality service. Today, its goal is to be an established world-class center of excellence for achieving and maintaining a fit, healthy, and ready force. To achieve that end, the CHPPM holds firmly to its values which are steeped in rich military heritage:

★ *Integrity is the foundation*
★ *Excellence is the standard*
★ *Customer satisfaction is the focus*
★ *Its people are the most valued resource*
★ *Continuous quality improvement is the pathway*

This organization stands on the threshold of even greater challenges and responsibilities. It has been reorganized and reengineered to support the Army of the future. The CHPPM now has three direct support activities located in Fort Meade, Maryland; Fort McPherson, Georgia; and Fitzsimons Army Medical Center, Aurora, Colorado; to provide responsive regional health promotion and preventive medicine support across the U.S. There are also two CHPPM overseas commands in Landstuhl, Germany and Camp Zama, Japan who contribute to the success of CHPPM's increasing global mission. As CHPPM moves into the 21st Century, new programs relating to fitness, health promotion, wellness, and disease surveillance are being added. As always, CHPPM stands firm in its commitment to Army readiness. It is an organization proud of its fine history, yet equally excited about its challenging future.

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14. ABSTRACT

Associations between mechanical task performance and injuries were examined in a study of male Army wheel vehicle mechanics. Initial testing on selected mechanical tasks, physical characteristics, and physical fitness was followed by screening of medical records for injuries occurring one year later. Of the 160 mechanics sought, only 104 completed the study. Cox regressions demonstrated little systematic association between time to perform mechanical tasks and overall injury risk (p=>0.26). When only mechanical work-related injuries were examined, mechanics with slower starter installation times tended to have higher injury risk. Higher injury risk was also associated with greater BMI, in consonance with the literature. However, higher injury risk was also associated with more push-ups and higher scores on strength measures which contradicted much of the literature. The small number of Soldiers may have resulted in an unrepresentative sample. Data on injury rates, anatomical locations of injuries, and activities associated with injury were very similar to a past investigation of mechanics.

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EXECUTIVE SUMMARY
A PROSPECTIVE STUDY OF INJURIES AND INJURY RISK FACTORS AMONG ARMY WHEEL VEHICLE MECHANICS
USACHPPM REPORT NUMBER 12-MA-7193B-06

1. INTRODUCTION. Previous investigations have examined outpatient injury rates and injury risk factors among Soldiers working in specific military occupational specialties (MOS) that include infantry, combat engineering, field artillery, military police, and armor. The major purpose of the present investigation was to examine among Army wheel vehicle mechanics, the association between mechanical task performance and injuries while controlling for other known injury risk factors. The project also sought to document injury rates, injury diagnoses, anatomical locations of injuries, and activities associated with injury.

2. METHODS. Participants were male volunteers recruited from the active duty population of Soldiers working in MOS 63B (light-wheel vehicle mechanic) or 63S (heavy-wheel vehicle mechanic) positions at Fort Bragg, North Carolina. Subjects were men, E-7 (Sergeant First Class) or below, and between the ages of 18 and 40. The study involved initial testing followed by screening of medical records one year later. Statistical power analysis indicated that 160 Soldier-mechanics would be needed but only 135 could be recruited and tested.

a. Initial testing was completed in a single session of about 4 hours during which each volunteer was assessed for his mechanical performance, physical characteristics, and physical fitness. The mechanical performance tests were selected from an ergonomic job analysis and included replacing a starter, replacing an alternator, changing a tire, and replacing a battery. For each task, removal times, rest times, replacement times, and total times were measured. All tasks were performed on a High-Mobility, Multi-Purpose, Wheeled-Vehicle (HMMWV), with the exception of the battery change which was performed on a HMMWV simulation. When each task was completed, Soldiers were asked to identify the typical frequency they performed the task during a normal work month.

b. Birth date (used to calculate age), height, and weight were obtained and body mass index (BMI, weight/height^2) was calculated. Body composition (fat mass, bone mass and lean mass) was measured using a dual-energy x-ray absorptiometry device (DEXA, Hollogic, Waltham, MA). Dynamic strength measures included one repetition maximums on both the bench press and the incremental dynamic lift (IDL). Isometric strength measures included peak maximal voluntary force exerted in the handgrip, back extension, elbow flexion, elbow extension, shoulder adduction, knee extension, and knee flexion. Army Physical Fitness Test (APFT) scores were obtained from the Soldier's last test. APFT events included maximal effort push-ups, maximal effort sit-ups (2 minutes each), and a 2-mile run for time. Soldiers completed a questionnaire concerning the frequency and duration of their participation in various types of exercise and sport activities.

c. Soldiers' medical records were examined for injuries that had occurred one-year after the initial testing. For each injury visit, investigators extracted the date of visit, type of visit (first or follow-up), activity associated with the injury, diagnosis, anatomical location of injury, disposition (final outcome of the visit), and days of limited duty (if any). For medical visits that did not contain an activity associated with the injury an attempt was made to contact the Soldier to obtain this information. Medical records did not contain deployment medical visits so dates on Soldier deployments was obtained from the Defense Manpower Data Center and deployed time was subtracted from total time at risk.

d. New injury rates (injuries/100 person-years) were calculated as: Σ initial injury visits / (Σ total time at risk for all Soldiers) X 100. A Soldier could have had more than 1 new injury. Limited duty day rates (days/100 person-years) were calculated as Σ limited duty days / (Σ total time at risk for all Soldiers) X 100. Total time at risk did not include deployment time since medical records did not contain medical visits on deployment. All continuous variables (mechanical performance, physical characteristics, and physical fitness measures) were split into 3 equal groups (tertiles) and Cox regression was used to examine associations between the tertiles and injuries.

3. RESULTS. Of the 135 men initially tested, medical records were obtained on 104 Soldiers. Reasons for missing records were primarily because of permanent changes of station (PCS) and Soldiers leaving military service (ETS).

a. The new injury rate for the 104 Soldiers was 115 injuries/100 person-years and the limited duty rate was 1159 days/100 person-years. Anatomic locations with the largest proportion of injuries were the knee (19%), lower back (17%), ankle (16%), and shoulder (9%). The activities that were associated with the largest proportions of injuries were physical training (25%), airborne activities (16%), sports (14%), and mechanical work (11%).

b. Cox regressions demonstrated that there was little systematic association between time to perform the mechanical tasks and overall injury risk ($p \geq 0.26$). There was a weak association between mechanical work-related injuries and time to install a starter (risk ratio (slowest tertile/fastest tertile) =3.5 (confidence interval=0.70-17.5, $p=0.13$)

c. For the physical characteristics, higher injury risk was associated with greater body weight, higher BMI, and higher lean mass ($p<0.10$ comparing tertile 1 to tertile 3). On the fitness measures, higher injury risk was associated with more push-ups and higher scores on the IDL or back extension ($p<0.10$ comparing highest to lowest performance tertiles). Generally, higher injury risk was associated with higher strength on any strength measure other than knee flexion.

4. DISCUSSION. This study found virtually no systematic relationships between overall injury risk and the various measures on the four mechanical performance tests. Only 9 injuries (about 10% of all the injuries) were directly related to mechanical work. Attempts to relate these 9 injuries to task performance resulted in very small numbers of cases in each tertile. Despite the limited statistical power, mechanical work-related injuries did tend to be higher among Soldiers who performed slower on the starter task.

a. Some other risk factors were found to be associated with injuries. Higher body weight and higher BMI increased the likelihood of injury in consonance with a previous study of wheel vehicle mechanics and much of the occupational injury literature. However, it was surprising that greater amounts of lean mass were associated with higher injury risk. In addition, more push-ups and generally greater strength were associated with higher injury risk contrary to much of the published literature on military populations. One likely explanation for these unusual findings was the small sample size. Because of problems with recruitment and retention, only about 65% (104/160) of the Soldiers required for the study based on statistical power analysis were actually tested and followed for injuries over the required 1-year period. The small number of Soldiers may have resulted in a less representative sample and interpretations of the data should consider this. Another possibility was that Soldiers with higher levels of physical fitness (and those with more fat-free or lean mass) might be more physically active and thus more exposed to physical hazards. However, post-hoc analysis of mechanical activity and sports and exercise activity was not able to demonstrate this.

b. Despite the small sample size, comparison of the current study with a past investigation of Army wheel vehicle mechanics demonstrated similar new injury rates, similar anatomical locations, and similar activities associated with injuries (although the proportion of airborne-related injuries was higher in the present study). Limited duty day rates were 13% to 40% lower in the present study compared to the past study suggesting that the injuries experienced in the current study were less severe.

5. CONCLUSIONS. The present investigation demonstrated little association between mechanical task performance and injuries in Army wheel-vehicle mechanics. There was a weak association between the starter installation task and specific mechanical work-related injuries. Higher body weight or BMI was associated with higher injury rates in consonance with a past literature. Surprising findings were that higher levels of fat-free mass, lower strength, and lower performance on push-ups were associated with lower injury rates. These latter data could not be explained by the self-reported frequency of mechanical activity or amount of exercise and sport. The small number of Soldiers (n=104) could have resulted in an unrepresentative sample. Data on injury rates, anatomical locations of injuries, and activities associated with injury were very similar to a past investigation examining the identical population.

A PROSPECTIVE STUDY OF INJURIES AND INJURY RISK FACTORS AMONG ARMY LIGHT-WHEEL VEHICLE MECHANICS USACHPPM REPORT NUMBER 12-MA-7193B-06

1. REFERENCES. Appendix A contains the references used in this report

2. INTRODUCTION.

a. Because of the requirements for regular vigorous exercise and realistic operational training, Army Soldiers are at high risk of injury. Installation Injury Reports routinely published by the Army Medical Surveillance Activity show that in each month of calendar year 2005, 7% to 9% of all Soldiers had at least one medical visit for an injury (http://amsa.army.mil/AMSA/amsa_home.htm). Injuries are a major problem in the military (1, 2) resulting in 5 to 22 times more days of limited duty than those arising from illnesses (3, 4). Identification of factors that put Soldiers at risk of injury is thus important for injury prevention efforts.

b. There are a number of investigations that have examined outpatient injury rates in Initial Entry Training (5-15), and among Soldiers working in specific military occupational specialties (MOS) in operational units. Specific MOS populations that have been examined include infantrymen (16-18), combat engineers (19, 20), field artillerymen (19), military police (21), and armor crewmen (22). In addition, we recently reported on a retrospective examination of injuries experienced by male and female wheel vehicle mechanics (23). That investigation identified injury rates, limited duty day rates, and activities associated with injury and examined a few injury risk factors. Among the male mechanics, elevated injury risk was associated with higher body weight and BMI. The number of risk factors examined in that study was relatively small and included only gender, age, height, weight, body mass index (BMI) and ethnicity.

c. The major purpose of the present investigation was to determine in Army wheel vehicle mechanics the association between mechanical task performance and injuries while controlling for other potential injury risk factors. The objectives of the study were to: 1) obtained mechanical performance measures and performance to injuries occurring in a subsequent one-year period, 2) examine other potential risk factors included Soldier physical characteristics, physical fitness, exercise and sports history, and frequency of mechanical work, and 3) replicate findings in our previous study of mechanics (23) by systematically examined injury rates, injury diagnoses, activities associated with injury, and the anatomical location of the injuries.

3. BACKGROUND. Studies focusing on Soldiers in specific MOS have examined injury hospitalizations (24), injury disability (25, 26), and outpatient injury medical visits (16-23, 27). Studies on outpatient injuries frequently include information on specific risk factors for injuries. As might be expected, injury rates and injury risk factors differ in the various MOS, which may be associated with the nature of the occupational tasks and the amount of physical training performed.

a. Injury Hospitalizations in Various Military Occupational Specialties. Analysis of injury hospitalizations in the 25 most populated enlisted MOS (accounting for about 50% of the Army enlisted population) was performed using the Total Army Injury and Health Outcomes Database (TAIHOD) with the survey period from 1990 to 1994 (24). Overall injuries were defined by International Classification of Diseases, Version 9 (ICD-9) codes 800-904, 910-957, and 960-995. Musculoskeletal injury hospitalizations were defined by ICD-9 codes 710-739. A summary of the results is shown in Table 1. Nine MOS were classified as "combat" and open to only men while the other 16 MOS were open to both men and women. Among men, the MOS with the highest injury hospitalization rates and musculoskeletal injury hospitalization rates were primarily among the combat (male only) specialties and medical specialists (MOS number 91A). Among women, the highest injury hospitalization rates were among the medical specialists (MOS number 91A), while wheel mechanics ranked first for musculoskeletal injury hospitalizations.

b. Injury Disabilities in Various Military Occupational Specialties.

(1) One study (25) examined musculoskeletal disability cases in the military during 1990-1994 using the US Army Physical Disability Database. Among the men, infantry Soldiers had the highest disability incidence at about 18/1000 Soldiers. Male wheel vehicle mechanics had the 14^{th} highest disability incidence at about 12 cases/1000 Soldiers. Among women, multichannel and single channel radio operators had the highest disability incidence (23 and 21/1000, respectively), with wheel vehicle mechanics ranking third at about 20 cases/1000.

(2) In a separate study, occupational back disability cases in the Army were examined in the 1990-1994 period using the Physical Disability Database (26). Among men, infantry Soldiers had the highest disability incidence at 4.6 cases/1000 and wheel vehicle mechanics had the 9^{th} highest disability rates at about 3.5 cases/1000. Among women, interrogators had the highest disability rate at 7.8 cases/1000 while wheel vehicle mechanics ranked third at 5.2 cases/1000.

Table 1. Number of Soldiers and Injury/Musculoskeletal Injury Hospitalization Rates in the 25 Most Populated MOS (24)

Military Occupational Specialty (Specialty Code)	Gender	Population (n)	Injury Hospitalization Rate (injury hospitalizations/ 1000 person-years)	Musculoskeletal Injury Hospitalization Rate (cases/1000 person years)
Infantryman (11B)	Men	194,384	26.0	24.8
Indirect Fire (11C)	Men	35,822	22.1	19.4
Heavy Anti-armor Weapons (11H)	Men	27,850	22.1	23.4
Fighting Vehicle Crewman (11M)	Men	71,738	22.4	17.3
Combat Engineer (12B)	Men	55,719	23.0	20.6
Cannon Crewmember (13B)	Men	96,059	21.4	19.1
Fire Support Specialist (13F)	Men	27,249	21.2	21.3
Cavalry Scout (19D)	Men	43,602	22.7	18.4
Armor Crewman (19K)	Men	73,069	22.1	18.7
Radio Operator-Maintainer (31C)	Men	23,459	17.8	18.7
	Women	2,902	13.8	24.8
Combat Signaler (31K)	Men	21,568	16.8	15.5
	Women	1,233	12.2	30.8
Power Generation Equipment Repairer (52D)	Men	27,944	16.8	19.5
	Women	1,364	13.9	29.3
Chemical Operations Specialist (54B)	Men	34,995	17.6	22.8
	Women	3,415	14.6	30.8
Wheel Vehicle Mechanic (63B)	Men	74,574	15.5	22.1
	Women	6,035	13.4	31.0
Track Vehicle Repairer (63H)	Men	21,996	13.7	23.6
	Women	1,266	6.4	21.3
Administrative Specialist (75B)	Men	43,062	11.7	20.5
	Women	35,265	7.9	19.6
Personnel Administrative Specialist (75B)	Men	20,380	12.5	19.5
	Women	6,776	8.6	19.0
Equipment Records & Parts Specialist (76C)	Men	18,955	14.7	18.2
	Women	5,740	12.0	20.6
Unit Supply Specialist (76Y)	Men	49,196	14.4	19.4
	Women	13,518	9.2	20.7
Petroleum Supply Specialist (77F)	Men	30,629	17.3	19.9
	Women	7,309	17.9	22.2
Motor Transport Operator (88M)	Men	60,836	19.0	21.7
	Women	10,022	14.3	24.1
Medical Specialist (91A)	Men	20,549	23.8	20.7
	Women	5,631	20.6	30.0
Medical Specialist (91B)	Men	59,609	16.8	24.8
	Women	13,472	12.4	28.1
Food Service Specialist (94B)	Men	57,189	15.8	19.2
	Women	15,284	14.2	19.2
Military Police (95B)	Men	88,138	15.3	20.4
	Women	10,293	15.3	24.0

c. Outpatient Injury Rates and Risk Factors in Specific Military Occupational Specialties.

(1) While injury hospitalization and disability data are important for describing the impact of the most serious injuries, they do not supply the entire picture. Outpatient medical visits account for a much larger proportion of medical encounters (3) and provide a more complete accounting of the size of the injury problem. Table 2 shows data extracted from studies examining outpatient injury rates in different MOS.

Table 2. Outpatient Injury Rates, Clinic Visit Rates, and Limited Duty Rates of US Army Soldiers in Various MOS

Study	Year Data Collected	Type of Unit	Rate (events/100 person-months)		Limited Duty Rate (days/person-year)[c]
			Injuries[cd]	Clinic Visits for Injuries[c]	
Tomlinson et al. (27)[a]	1984-1985	Infantry	12.2	ND	ND
		Infantry	18.6	ND	ND
		Special Forces	12.1	ND	ND
		Rangers	10.1	ND	ND
		Aviation/Artillery	4.5		
Knapik et al. (16)[b]	1989-1990	Infantry	11.8	18.3	11.8
Reynolds et al. (17)	1989-1990	Infantry	ND	15.1	6.1
Reynolds et al. (19)	1996	Combat Engineers	ND	16.8	5.9
		Artillery	ND	12.3	5.7
Smith and Cashman (18)	1997-1998	Infantry	8.4	ND	15.7
Hauret et al. (21)	2002	Military Police	9.2	19.2	32.5
Darakjy et al. (22)	2002	Armor	5.7	11.0	15.8
Knapik et al. (23)	2003-2004	Wheel Vehicle Mechanics	Men 10.3 Women 13.0	Men 18.6 Women 19.8	

[a]Annualized rates based on 8 weeks of data collection
[b]Annualized rates based on 6 months of data collection
[c]ND=No data
[d]An injury is the first visit for a particular type of physical damage to the body. A Soldier could have more than one injury.

(2) Tomlinson et al. (27) monitored Soldiers reporting to 4 Troop Medical Clinics (TMCs) at Fort Lewis, Washington over an 8-week period. They also looked at injury hospitalizations but since the large majority of visits were outpatient (86%), the study is considered in this section. Injuries were recorded as Soldiers entered the clinic and a questionnaire was used to obtain additional information from the Soldiers. Injuries examined were primarily traumatic and environmental (heat/cold); overuse injuries were apparently not considered. Among 15,295 Soldiers in the 9th Infantry and 1st Corps, there were 478 new injuries for an annualized rate of 81 injuries/100 person-years (6.8 injuries/100 person-months). Injury rates differed in various TMCs supporting different types of military units. Fifty-five percent of injuries were associated with sports and exercise. Forty percent of the injured Soldiers were returned to duty, 52% were given limited duty, 14% were hospitalized, and 5% were assigned to quarters. Differences were noted among 2 infantry battalions, a ranger battalion, and a Special Forces group as shown in Table 2. Of the 335 injuries that occurred in garrison, locations included the gymnasium/athletic field (38%), quarters/neighborhood (16%), motor pool/hanger (12%) and field and forest (6%). All Soldiers (regardless of MOS) were combined and a case-control study was conducted (controls were Soldiers reporting to the clinic who were uninjured). It was found that the odds of injury were higher among Soldiers who were men (odds ratio (OR)=2.5(95% confidence interval (95%CI)=1.4-4.7)), younger (OR (17-21 yrs/22-46 yrs)= 1.4(95%CI=1.1-1.9)), of lower rank (OR (E1-E3/E4-E9)=1.4 (95%CI=1.1-1.8)), in combat units (OR(combat/combat service or service support)=1.5 (95%CI=1.1-2.0)), single (OR (single/married)=1.4 (95%CI=1.1-1.8)), lived in on-post housing (OR (on-post/off-post)=1.5 (95%CI=1.2-2.0)), and exercised longer during the week (OR (0-9 hrs/ ≥10hrs)=1.8(95%CI=1.4-2.4)). Injury was not associated with race, alcohol consumption, or history of injury in the last 6 months.

(3) Knapik et al. (16) examined injuries over a 6-month period among 298 male Soldiers assigned to a light infantry battalion at Fort Richardson, Alaska. Injuries were abstracted from the Soldiers' medical records. Additional data obtained from unit

records included age and Army Physical Fitness Test (APFT) scores. The APFT consisted of a maximal effort push up event (2 minutes), a maximal effort sit-up event (2 minutes), and a 2-mile run for time. Injuries were defined more broadly than by Tomlinson et al (27) and included traumatic, overuse, and environmental injuries. Despite the difference in the injury definition, injury rates were comparable to those reported by Tomlinson et al. (27). Over the 6-month period, 51% of the Soldiers experienced one or more injuries with a total of 212 injuries and 327 clinic visits. The annualized injury rate was 142 injuries/100 person-years (11.8 injuries/100 person-months). The annualized clinic visit rate was 219 visits/100 person-years (18.3 visits/100 person-months). Soldiers were given a total of 1764 days of limited duty for an annualized rate of 11.8 days/person-year. Injury risk was elevated among younger Soldiers (relative risk (RR) (<20yrs/>24yrs)=1.1), those with slower 2-mile run times (RR (slowest 25%/fastest 25%)=1.6) and those performing fewer sit-ups (RR=(lowest 25%/highest 25%)=1.5).

(4) Reynolds et al. (17) examined injuries over a one-year period among 181 male light infantry Soldiers at Fort Drum, New York. Soldiers completed a questionnaire that inquired about their lifestyle and past injuries. Direct measurements were taken of their height, weight, body fat (circumference technique), flexibility (sit-and-reach test), and hand grip strength. APFT scores were obtained from the unit. Injuries were obtained by screening medical records and injuries were defined similar to Knapik et al. (16). During the 1-year period, 101 Soldiers (56%) experienced one or more injuries for which they made 328 clinic visits for an annualized clinic visit rate of 182 visits/100 person-years (15.2 visits/100 person-months). Soldiers were given a total of 1103 days of limited duty for an annualized rate of 6.1 days/person-year. Lower extremity and low back injuries were related to body fat (relative risk (RR)(fattest quintile/leanest quintile)=1.7), slower 2-mile run time (RR (slowest quintile/fastest quintile)=1.6), fewer sit-ups (RR(fewest quintile/most quintile)=1.5), and cigarette smoking (RR(>10 cigarettes per day/nonsmokers)=1.7). BMI showed a bimodal relationship with the highest and lowest quintile demonstrating elevated risk compared to the middle quintile (RR=2.2 and 1.7, respectively). In multivariate analysis, smoking history and 2-mile run times were independent risk factors for injury.

(5) Reynolds et al. (19) examined injuries over a 1 year period among 125 male combat engineers and 188 male combat artillerymen at Fort Drum, New York. Soldiers completed a questionnaire on their age, ethnicity and cigarette smoking history. Soldier height, weight and APFT scores were obtained from the units involved in the study. Injuries were obtained from medical records and injury definitions were consistent with previous studies (16, 17). During the 1-year period, 108 engineers (86%) experienced one or more injuries and made 252 clinic visits. Of the combat artillerymen, 124 (66%) experienced one or more injuries and they made 277 clinic visits. The annualized clinic visit rate for the combat engineers was 201 visits/100 person-years (16.8 visits/100 person-months) and that for the combat artillerymen was 147 visits/100 person-years (12.3 visits/100 person-months). Days of limited duty were 743 for the combat engineers (5.9 days/person-year) and 1078 for the artillerymen (5.7 days/person-year). The engineer and artillerymen data were combined to examine risk factors for specific types

of injuries. Risk factors for lower extremity pain included shorter height (OR(<170 cm/ ≥ 170 cm)=2.9 (95%CI=1.2-6.7)), and ethnicity (OR(Caucasian /Non-Caucasian)=1.9 (95%CI=1.2-3.0)). For low back pain, greater body weight was a risk factor (OR(<90 kg/ ≥90 kg)=2.5 (95%CI=1.2-5.5)). For strains and sprains, risk factors included shorter stature (OR(<170 cm/ ≥170 cm)=2.3 (95%CI=1.2-4.3)) and higher BMI (OR (≥25 kg/m^2/<25 kg/m^2)=2.1 (95%CI=1.2-3.4)).

(6) Reynolds et al. (20) reported a separate study of injuries among 147 combat engineers. Injuries over a 1-year period were obtained by screening medical records and APFT scores were acquired. Sixty-eight percent of the Soldiers had one or more injuries. Soldiers with slower run times tended to have more injuries (RR (slowest 25%/fastest 25%)=1.5). Neither push-ups (p=0.92) nor sit-ups (p=0.74) were associated with injury.

(7) Smith and Cashman (18) examined injuries over a 13-month period among 339 infantry Soldiers of the 25th Infantry Division (Light) at Schofield Barracks, Hawaii. Injuries were obtained by screening medical records. No injury definition was provided. During the period, 213 Soldiers (63%) experienced one or more injuries and there were a total of 372 injuries. The annualized injury visit rate was 101 injuries/100 person-years (8.4 injuries/100 person-months). Days of limited duty totaled 5775 during the 13-month period for a annualized rate of 15.7 days/person-year. Activities associated with injury were obtained in 91% of the new injury cases (339/372) and the major activities were physical training (50%), foot marching (16%), job/field (14%), off-duty sports (8%), and off-duty other activities (14%). It was reported that Soldiers in lower enlisted ranks (E1-E5) were more likely to be injured than higher ranking Soldiers (E6-O6) but the data was not presented. Cigarette smokers were not more likely to get injured than non smokers but these data were also not presented.

(8) Hauret et al. (21) examined injuries over a 1-year period among 268 male military police at Fort Riley, Kansas. Injuries were obtained from medical records and injury definitions were consistent with past studies (16, 17, 19). Age, race, height, and weight were obtained from the medical records and APFT scores were obtained from the military unit. During the 1-year period, 140 Soldiers (52%) experienced one or more injuries, there were 213 new injuries, and 462 clinic visits. When only time assigned at Fort Riley was considered, the annualized new injury rate was 110 injuries/100 person-years (9.2 injuries/100 person-months). Soldiers were given a total of 6,529 days of limited duty (32.5 days/person-year). Fifty-two percent of injuries with known causes were related to physical training or sports while 34% were related to military training activities. Risk factors related to injury included age and higher BMI in both univariate analyses (age (continuous variable), RR=1.04 (95%CI=1.01-1.06); BMI (RR(highest quartile/lowest quartile)=2.5(95%CI=1.4-4.5)) and multivariate analysis (age (as a continuous variable), RR=1.03 (95%CI=1.00-1.06), BMI, RR(highest quartile/lowest quartile)=2.2(95%CI=1.8-4.0)).

(9) Darakjy et al. (22) examined injuries over a 1-year period among 426 armor crewmen at Fort Riley, Kansas. Injuries were obtained from medical records and injury definitions were consistent with past studies (16, 17, 19). Age, height, weight, race, and

APFT scores were obtained from the military unit. During the 1-year period, 139 Soldiers (33%) experienced one or more injuries; there were 205 new injuries, 397 clinic visits, and 4747 days of limited duty. When only the time that Soldiers were assigned to Fort Riley was considered, the annualized new injury rate was 46 injuries/100 person-years and 15.8 limited duty days/person-year. In multivariate analysis, high BMI (RR(highest quartile/lowest quartile)=2.3 (95%CI=1.1-4.9)) and lower rank (RR(lower enlisted/officers)=2.3 (95%CI=1.1-4.9)) were independent injury risk factors.

(10) Knapik et al. (23) examined injuries over a 1-year period among Army wheel vehicle mechanics assigned to Fort Bragg, North Carolina. Injuries were obtained from the medical records of 518 male and 43 female mechanics and injury definitions were consistent with past studies (16, 17, 19, 22). Weight, height, age, and ethnicity were also extracted from the medical records. The person-time injury rates for men and women were 124 and 156 injuries/100 person-years, respectively. Limited duty days for men and women were 21 and 20 days/person-year, respectively. For the men, 34% of the injuries involved the upper body, 19% were in the lower back and 46% were in the lower body. For women, 24% of the injuries involved the upper body, 10% were in the lower back, and 62% were in the lower body. Activities associated with injury included (in order of incidence) physical training, mechanical work, sports, airborne-related activities, road marching, garrison/home activities, and chronic conditions. Among the men, elevated injury risk was associated with higher body weight and higher BMI. Injury risk factors were not examined among the women because of the small sample size.

d. Summary of Studies on Various Military Occupational Specialties.

(1) Injury rates and injury risk factors vary by MOS. Infantrymen are the most studied MOS, but it is difficult to compare injury rates among infantrymen across studies because of differences in injury case definitions (16, 27) or lack of any definition at all (18). In the Tomlinson et al. study (27), two very different injury rates were reported for two separate infantry units suggesting that rates can vary among units even within the same MOS using the same injury definition. However, Tomlinson et al. collected only 2 weeks of data, then calculated annualized rates from these data. This short period of time may have introduced some data instability. For example, major differences in the type or intensity of training in this period or seasonal variations (28) could affect the data. In the two studies of infantrymen that used a similar definition of injury (16, 17) the clinic visit rate was similar (injury rate was not reported in one study). The few studies on other MOS suggest that compared to infantry Soldiers, the injury rate for armor crewmen (22) and for aviation/artillery units (27) are lower; however, the injury rate for military police (21) may be higher than some infantry units (18). Also the clinic visit rate for military police is the highest among all occupational groups for which this measure has been reported.

(2) Person-time limited duty days have also varied widely in different studies. This may be attributed to how well medical care providers have documented the days of limited duty in the medical records. Future studies examining limited duty days from

medical records should report cases for which a profile (duty limitation) was prescribed but no limited duty days recorded in the medical record.

(3) Risk factors that have been studied in several MOS include BMI, physical fitness (aerobic endurance measured by 2-mile run times and muscular endurance measured by push-ups and sit-ups) and age. The strength and direction of the association of these variables with injury appear to vary by MOS.

(4) High BMI was an injury risk factor among military police, armor crewmen and male wheel vehicle mechanics (21-23), but the relationship was bimodal (higher risk at both BMI extremes) in infantry Soldiers (17). Body fat did not share the bimodal relationship with injuries in infantrymen (the only MOS where it has been examined in conjunction with injuries); rather, infantrymen with higher body fat were at higher risk and those with lower body fat were at lower risk (17). Generally BMI is taken as a marker of body fat since the correlation between these two variables is 0.70 (29-31). However, there was some dissociation of the relationship between BMI and body fat in infantrymen since they did not follow the same relationship with regard to injuries. This difference may be due to the arduous nature of infantry training and the disadvantage that Soldiers with low BMI have in this environment. Soldiers with low BMI have less body mass for their height, reflecting less total body tissue, including lower muscle mass. Infantrymen are frequently engaged in tasks like load carriage, lifting, and carrying and it is possible that those with low BMI might be more susceptible to injury because they have less total tissue over which to spread the load resulting in more stress per unit of total tissue. They may tire more rapidly, resulting in changes in gait and/or specific movement patterns (32-34). This would put unusual stress on portions of the body unaccustomed to this stress, resulting in a higher likelihood of injury. Although military police and armor crewmen perform some tasks that are similar to the infantry (e.g., physical training, lifting, manual carrying) the nature of their work and training may be such that low BMI does not increase injury risk; the only increase in risk is at higher BMI levels in these occupational groups.

(5) Low aerobic fitness is a risk factor among infantry Soldiers (16, 17), military police (21), armor crewmen (22) and combat engineers (20). However, when considered in a multivariate analysis with BMI, aerobic fitness remains as an independent risk factor for infantrymen but not for military police or armor crewman (multivariate analyses were not performed on engineers). The fact that 2-mile run time is an independent risk factor for infantrymen may reflect the importance of a high level of aerobic fitness for the tasks performed by Soldiers in this MOS. Although aerobic fitness is still an injury risk factor for military police and armor crewmen, BMI appears to be a more important factor.

(6) Besides low aerobic fitness, low sit-up performance is also an injury risk factor among infantrymen (16, 17). However, there is virtually no relationship between injuries and sit-ups among military police, armor crewmen, or combat engineers (19, 20, 22). This may reflect the importance of abdominal muscular endurance for infantrymen which is possibly related to the rigorous nature of their occupational tasks.

(7) Younger age increases risk in infantry Soldiers (16) but older age increases risk among military police (21) and has less importance for armor crewmen (22) and wheel vehicle mechanics (23). In the infantry, younger Soldiers may perform more of the arduous occupational tasks and thus be more susceptible to injury than older Soldiers who are likely to have higher rank and be in supervisory or staff positions. It is not clear why older Solders were more often injured among military police.

e. Occupational Tasks of Wheel Vehicle Mechanics.

(1) An ergonomic analysis was conducted of the occupational tasks performed by Army wheel vehicle mechanics (35). Two steps were involved in the analysis, 1) a review of available documents related to the MOS and 2) interviews with subject matter experts. Documents reviewed included Army regulations, 63B training documents, Army Training and Doctrine Command (TRADOC) documents, and MOS reports. Focus group interviews were conducted with individuals working in the MOS. From a list of the 27 most physically demanding tasks in the MOS (developed from the document review), the mechanics identified the 10 tasks with the highest physical demands. These were 1) replacing a radiator, 2) replacing a starter, 3) correcting a malfunction of a knuckle and geared hub, 4) replacing a half shaft, 5) replacing the front and rear brake pads, 6) replacing universal joints, 7) correcting an alternator malfunction, 8) replacing a propeller shaft, 9) correcting a battery malfunction, and 10) maintaining assigned tool kit.

(2) Informal interviews with Army wheel vehicle mechanics at Fort Bragg, North Carolina indicated that their normal duties involve both normal soldiering activity as well as mechanical work. A typical day in garrison involved physical training for about one hour (0630-0730). The Soldiers then had about 1.5 hours for hygiene (shower, clean up) and breakfast (0730-0900). The Soldier reported to the motor pool at 0900. In the motor pool, Soldiers performed mechanical work on vehicles for the remainder of the day which normally lasted from 0900 to 1700. While working in the motor pool mechanics were involved in testing equipment, troubleshooting, and changing and repairing vehicle parts. Near the end of the work day Soldiers cleaned up the working area. Generally a break was taken about 1200-1300 for lunch. Senior personnel (pay grades E-5 to E-7) spend some time in the shop office doing paperwork while junior personnel (pay grades E-2 to E-4) typically spent the entire day working in the shop. Besides these typical activities, the Soldiers also had Non-Commissioned Officer Professional Development (NCOPD) classes or tactical training about once a week (1/2 day). Airborne operations were conducted about one time per month or at least once per quarter. On about a quarterly basis, Soldiers were involved in a field training exercise where they spend 3 to 7 days (sometimes longer) in the field. In the field, Soldiers were generally awakened at 0500, did hygiene (clean up, brushing teeth, shaving), and spent the rest of the day repairing and recovering vehicles. Sleep time in the field was dependent on the amount of equipment that required repair. All Soldiers rotated on guard duty both day and night, and the amount of time on guard duty was dependent on the exercise scenario.

f. Civilian Studies of Auto Mechanics. Civilian studies of injuries to automotive mechanics are difficult to find because many occupational studies tend to examine broad occupational groups (e.g., services, construction, transportation, etc.) and do not partition out particular specialties. A study examining US industries in 1996 found that the "motor vehicle and car body" industry had the sixth highest incidence rate for nonfatal injury and illness in the US (36). Data on nonfatal occupational injuries and illnesses from the Survey of Occupational Injuries and Illnesses conducted by the US Department of Labor, Bureau of Labor Statistics shows that in 2005 in the "repair and maintenance" sector, the non-fatal injury rate was 3.9 cases/100 full time workers (37). For automotive mechanics, the cost of fatal and non-fatal occupational injury was estimated to be about $65 million per year, ranking 21st among 419 occupations in the United States (38). A study on mortality among Danish auto mechanics found that mortality due to "external causes" (ICD-9 E-codes E001-E999, primarily accidents and poisoning) was 1.3 times higher than in a comparable occupational group with similar strength/fitness demands, social class, and geographic distribution (carpenters, electricians, instrument makers, dairymen, upholsterers, and glaziers) (39).

4. METHODS.

a. Subjects.

(1) Volunteers were recruited from the active duty population of Soldiers working in MOS 63B (light-wheel vehicle mechanic) or 63S (heavy-wheel vehicle mechanic) positions at Fort Bragg, North Carolina (NC). Subjects were men, E-7 (Sergeant First Class) or below, between the ages of 18 and 40. In several small groups, mechanics were briefed on the purposes, procedures, and risks of the study and those who agreed to participate signed a volunteer agreement. All procedures complied with Army Regulation 70-25 on the use of volunteers in research.

(2) The number of subjects required for the study was determined using EpiInfo Version 6. A confidence level (1-alpha) of 95% and power (1-beta) of 80% were assumed. A difference in risk of a factor of 1.5 (risk ratio) was considered of practical significance. The expected cumulative injury incidence of men for a 1-year period was expected to be 49% . A decrease in risk of 1.5 represents an injury rate of 33%. The number of men needed under these assumptions was 160.

b. Study Design.

(1) This study involved initial testing followed one year later by screening of medical records. Initial testing was completed in a single session of about 4 hours during which each volunteer was assessed for his mechanical performance, physical characteristics, physical fitness, and exercise/sports history. The mechanical performance testing was conducted in a motor pool area of the 1st Corp Support Command (COSCOM) at Ft Bragg, North Carolina. Physical characteristics, most physical fitness measures, and exercise/sports history were obtained at the United States Army Research

Institute of Environmental Medicine (USARIEM) Medical Research Laboratory located in Womack Army Medical Center at Fort Bragg, North Carolina. One year after the initial testing the medical records of the Soldiers were reviewed and injuries were recorded. The association between injuries and the initial tests were examined as described in the Data Analysis section.

(2) Initial testing was conducted in two separate time periods, 29 March to 1 April 2004 (Period 1) and 14 to 17 June 2004 (Period 2). Soldiers tested in Period 1 had their medical records screened for the period 2 April 2004 through 1 April 2005. Soldiers tested in Period 2 had their medical records screened for the period 18 June 2004 through 17 June 2005.

c. Initial Testing. Initial testing involved 1) the mechanical performance measures, 2) obtaining physical characteristics of the Soldiers, 3) obtaining muscle strength measures, 4) obtaining APFT scores, 5) and administration of an Exercise and Sports Questionnaire.

(1) Mechanical Performance.

(a) Specific tests were developed to examine mechanical performance. Developing these tests first involved a determination of the most physically demanding tasks performed by vehicle mechanics followed by development of performance measures to quantify these tasks.

(b) A five-phase job analysis was conducted to identify the most physically demanding tasks of wheel vehicle mechanics. Details of the procedures to identify these tasks are described in another publication (35). Briefly, Phase 1 was a review of documents that included task descriptions, maintenance guidance, training packages and lesson plans, performance standards and criteria, and any required abilities (cognitive, psychomotor, physical, sensory/perceptual, interactive/social, and knowledge/skills). Phase 2 involved expert ratings. Focus groups of 10, 63B instructors and Non Commissioned Officers (NCOs) and 37 junior enlisted Soldiers rated the 10 most physically demanding tasks in the MOS from a comprehensive list of 27 tasks identified in the document review. These tasks are shown in Table 3. Phase 3 involved a written survey from 82 63B Soldiers at Ft Bragg North Carolina. Responses to this survey identified the top 10 physically demanding tasks and subtasks and provided information about the type of physical demand, the frequency and duration of the tasks, and rated physical exertion required to complete the tasks. Phase 4 was the task analysis and involved video recording of the 4 most physically demanding tasks and subtasks. Phase 5 involved use of the video recording to construct task simulations. The 4 most physically demanding tasks identified were replacing a starter, replacing an alternator, changing a tire, and replacing the battery. All tasks involved a High-Mobility, Multi-Purpose, Wheeled-Vehicle (HMMWV).

(c) One of the tasks selected, changing a tire, was not specifically listed in the top 10 physically demanding tasks; however, removing/replacing a tire is the most physically demanding sub-task for seven of the top 20 physically demanding tasks (correct malfunctioning knuckle/gear hub, replace front and rear brake pads, replace master cylinder, replace brake shoes, replace brake calipers, replace brake rotors, and replace hand brake shoes). Since it is the most demanding sub-task for many of the physically demanding tasks and is done frequently by nearly all 63B, it was selected for testing.

Table 3. Top 10 most physically demanding tasks performed by 63B Soldiers

Replace radiator on a light-wheeled vehicle
Replace Starter on a light-wheeled vehicle
Correct malfunction of knuckle and geared hub on a light-wheeled vehicle
Replace half-shaft on a light-wheeled vehicle
Replace front and rear brake pads on a light-wheeled vehicle
Replace universal joints on a light-wheeled vehicle
Correct alternator malfunction
Replace propeller shaft
Correct malfunction of batteries on a light-wheeled vehicle
Maintain assigned toolkit

(d) Once the tasks had been identified, they were pilot tested and the performance measures were developed. Each task (replacing a starter, replacing an alternator, changing a tire and replacing a battery) involved removing an object, a rest period, then replacing the object. Removal time, rest time, replacement time, and total time were measured. During the study, the four tasks were performed in a random order. Prior to performing the task, the Soldier received an explanation and demonstration. All 4 tasks were performed on HMMWVs, with the exception of the battery change as described below.

(e) Removing and installing an alternator involved reaching into the engine compartment and holding and positioning the alternator with one hand while unscrewing the nuts that held the alternator in place with the other hand. The alternator was located 45" from the ground, and 16" into the engine compartment. The unmodified AMA-5102UT (60-amp) alternator used in these trials weighed 35 lbs. The Soldier was instructed to remove and install the alternator, working at a typical pace and to complete the task to the performance standard specifications (to the point of tightening the fan belts). The time to remove and replace the alternator, as well as the rest time between these actions, was recorded.

(f) Removing and installing a starter motor involved working under the vehicle in a supine position on a creeper with the arms extended. The starter was held and positioned with one hand while a wrench was used to unfasten the nuts that held it in place with the other hand. This sub-task required a forward/overhead reach of 23" from the ground. The unmodified starter motor weighed 55 lbs. The soldier was instructed to remove and install the starter motor, working at a typical pace and to complete the task to the performance standard specifications. The times to remove and replace the starter, as well as the rest time between these actions, were recorded.

(g) Removing and replacing a tire involved raising the vehicle with a jack such that the tire was 2" off the ground, with tire chucks in place to prevent tire rotation. The soldier loosed and removed the eight lug nuts, then pulled the wheel off the wheel assembly. The Soldier removed the wheel chucks and laid the wheel down in a marked area next to the vehicle. To replace the tire, the tire was lifted from its side-lying position, rolled next to the hub, lifted 2", to a position back on the wheel assembly. The tire chucks were placed under the tire, and the lug nuts were replaced and secured. The unmodified bias tire weighed 120 lbs. The soldier was instructed to remove and replace the tire, working at a typical pace and to complete the task to the performance standard specifications. The time to remove and replace the tire, as well as the rest time between these actions, was recorded.

(h) The battery change was performed on a simulator, which duplicated the HMMWV battery object dimensions. Actual components of the HMMWV were incorporated into the battery change mock-up to increase the fidelity and simulation realism. While working in a standing, forward leaning position at the side of the simulation station, the Soldier removed the bolts of the metal battery guard, and pulled it off. The cables were then removed. One at a time, the Soldier lifted each of the two batteries out of the simulator, and lowered them to a marked area on the ground. The Soldier then put each battery back into the battery compartment and replaced the cables and guard. The task required a forward reach of 15". The batteries were located 35" from the ground. The unmodified batteries weighed 74 lbs each. The soldier was instructed to remove and replace the battery, working at a typical pace, and to complete the task to the performance standard specifications. The time to remove and replace the batteries, as well as the rest time between these actions, was recorded.

(i) When each task was completed, Soldiers were asked to identify the typical frequency that they performed the task. (<Monthly, Monthly, 2-3 times/wk, 1-2 times/wk, 3-4 times/wk, Daily). In order to estimate the overall frequency at which the Soldiers performed the most physically demanding tasks in their MOS, a "Mechanical Frequency Index" was calculated. For this index, numeric values were assigned to each response category as follows: <Monthly=1, Monthly=2, 2-3 times/wk=3, 1-2 times/wk=4, 3-4 times/wk=5, Daily=6. Numeric values for the mechanical frequency index were obtained by summing the frequency values for each of the 4 tasks. The index could range from 4 ("<Monthly" on all 4 tasks) to 24 ("Daily" on all 4 tasks).

(2) Physical Characteristics.

(a) Subjects were asked their birth date (used to calculate age) and military rank. Height was measured using a stadiometer (Model GPM, Seritex, Inc, Carlstadt, NJ). Body weight was measured using a digital scale with subjects in their physical training uniform (shirts, shorts, underclothes and socks). Ethnicity was obtained from the physical examination form in the medical record (Standard Form 88, Report of Medical Examination) determined on entry to service at the Military Entrance Processing Station (MEPS).

(b) Body composition was measured using a dual-energy x-ray absorptiometry device (DEXA, Hollogic, Bedford, MA). The Soldier was dressed in physical training uniform without shoes and laid face up on a DEXA scanner table. They were laterally centered on the table with hands palm downward. Velcro straps were used to keep the knees together and support the feet so they tilted 45° from the vertical. Scanning was in slices from head to toe using the 6-minute scanning speed. Quantitative

Digital Radiography (QDR) for Windows software provided an estimate of percent body fat, fat mass, bone mass, bone mineral density, fat-free mass, and lean mass (fat-free mass minus bone mass).

(3) Muscle Strength Measures.

(a) The two tests of dynamic strength were the bench press and dynamic lift. The 7 tests of isometric strength included the handgrip (40), back extension (41), elbow flexion, elbow extension, shoulder adduction, knee flexion and knee extension.

(b) The bench press was performed while lying supine on a flat bench beneath a standard Olympic style weight bar on a bench press exercise rack (Body Masters, Rayne, LA). Proper lifting procedures were described and demonstrated prior to testing. Keeping the feet flat on the floor, the volunteer lowered the weight bar from a straight arm position, down to the chest and returned to a straight arm position without bouncing the load off the chest. Volunteers performed the movement in an unloaded condition then a warm-up of 5-10 repetitions at 40-60% estimated maximum was followed by a 3-5 minute rest. Three repetitions at 60-80% maximum were completed, again followed by 3-5 minutes rest. Approximately three to five subsequent lifts were then made to determine the 1-repetition maximum (1RM), with loads increased by 5-10% each attempt. Additional lifts were completed as necessary. Three to five-minutes of rest were provided between each near-maximal lift attempt. A successful lift was one that was completed through a full range of motion without deviation from proper form. Two spotters assisted and coached on each lift (42).

(c) Lifting strength was measured using the incremental dynamic lift (IDL) (8, 43). The test simulated lifting a box with handles from ground level onto a 2-1/2 ton truck. Volunteers lifted handles attached to the carriage of a weight stack machine vertically from 20 cm to 152 cm. The carriage moved vertically between two guide rails. The lift began with the Soldier grasping the handles of the weight carriage and assuming a bent-knee, straight back position with the head up and feet shoulder width apart. The load was accelerated upward as the Soldier straightened his legs and pulled up on the handles of the load carriage, using an overhand grip. The wrists were simultaneously rotated under the handles and the load was elevated to the 152 cm mark on the vertical guides. The initial load was 18.2 kg and was increased in 9 kg increments until the volunteer began to experience difficulty. At this time the increments were reduced by half (4.5 kg) until the volunteer was unable or unwilling to complete the lift using a safe technique. Volunteers were provided detailed instruction on lifting technique and practice trials. Inter-trial rest periods of at least one minute were allowed at near maximum loads (44, 45).

(d) The testing procedures for all 7 isometric tests were identical. The volunteer was properly positioned and secured in the testing apparatus. Three maximum effort trials were performed with a minimum of 1-minute rest between trials. The highest two trials within 10% of one another were averaged for the final score. Additional trials were performed as necessary, up to a maximum of five trials, to obtain two trials that differed by no more than 10%.

(e) Isometric handgrip strength was measured using a device and procedures described previously (40). The grip device contained a tension-compression transducer (BLH Electronics, model C2M1, Waltham, MA) attached to a digital-peak-tension readout (BLH Electronics transducer indicator, model 450A, Waltham, MA). The test was conducted in a seated position with the forearm resting on a padded table surface. The handgrip apparatus was adjusted to an angle of 150° at the metacarpalphalangeal joint and 110° at the proximal interphalangeal joint of the third finger. While keeping the forearm on the padded table surface, the Soldier increased his grip force to maximum over a period of 1-2 seconds. Jerking movements, or lifting the forearm off the pad resulted in a re-trial. Handgrip strength of the dominant hand was measured.

(f) Isometric back extension strength was measured using a portion of the Triple Strength Device (41). The Soldier faced an upright pole, with the hips against the padded support. A padded strap was cinched around the Soldier's shoulders one inch below the acromium process. On command, the Soldier extended his back against the strap restraint, while keeping contact with the hip plate. The Soldier maintained maximum force for 3-4 seconds, with no jerking movement permitted. The back extension device contained a tension-compression transducer (BLH Electronics, model C2M1, Waltham, MA) attached to a digital-peak-tension readout (BLH Electronics transducer indicator, model 450A, Waltham, MA) that provided the peak force.

(g) Three isometric strength measures (elbow flexion, elbow extension, and shoulder adduction) were obtained on the Quantitative Muscle Assessment System (QMAS, Gainesville, GA). This device consisted of an adjustable, padded examining table, an orthopedic frame, and force transducers.

(h) Isometric elbow flexion and extension of the right arm was measured with the QMAS while the Soldier was lying supine with the upper arm strapped to a padded surface, parallel to the body. The forearm was attached to a load cell using a padded wrist cuff. The elbow-testing angle was 90° for both tests. On command, the volunteer contracted the forearm flexors or extensors, building to maximum over a 1-2 sec period and maintained that force for an additional 2-4 sec. The computerized system recorded the peak force produced from each contraction into a database for later analysis.

(i) Isometric shoulder flexion strength was measured with the QMAS while the Soldier was lying down with the arms extended straight up at a right angle to the body and the floor. A shoulder-width handle was grasped with the hands palm upward. On command, the Soldier pulled toward the head, building to maximum over a 1-2 sec period and maintained the force for an additional 2-4 sec. The handle was attached by adjustable cable to a force transducer (SM 1000) mounted on a traction frame. The peak force was recorded by a computerized system into a database for later analysis.

(j) Isometric knee flexion and extension strength of the right knee was measured using the Biodex Isokinetic Measurement System. The subject was seated, with hips and legs secured with Velcro straps. The dynamometer head was aligned with the geometric center of the lateral femoral condyle. A padded cuff on the lower portion of the Biodex lever arm was attached at the ankle with Velcro straps. The knee angle was 90°. The subject pushed forward against the cuff as if to extend the leg (knee extension) for three maximum isometric trials, and then pushed backward against the cuff (knee flexion) as if to flex the leg for three maximum effort isometric trials. The two highest of three maximum force scores (for each muscle group individually) within 10% of one another were recorded as the final score.

(4) Army Physical Fitness Test (APFT).

(a) The APFT consisted of 3 events, push-ups, sit-ups, and a 2-mile run. For push-up, the Soldier was required to lower his body in a generally straight line to a point where his upper arm was parallel to the ground, then return to the starting point with elbows fully extended. For sit-up, the Soldier bent his knees at a 90° angle, interlocked his fingers behind the head, and a second person held the Soldiers ankles to keep the Soldier's heels firmly on the ground. The Soldier raised his upper body to a vertical position so that the base of the neck was anterior to the base of the spine and then returned to the starting position. The number of push-ups and sit-ups successfully completed in 2 minutes were recorded. Run performance was measured as the time to complete the 2-mile distance.

(b) The Soldier's unit was contacted by telephone and asked for the most recent APFT values. The number of push-ups completed, the number of sit-ups completed, and the two-mile run time was recorded (raw scores).

(5) Exercise and Sports Questionnaire.

(a) Soldiers completed a questionnaire concerning the frequency and duration of their participation in various types of exercise and sports activities and their assessment of their overall physical activity. The questionnaire is at Appendix B.

(b) In order to estimate the overall frequency of exercise and sports, an "Exercise and Sports Index" was calculated. This was the arithmetic sum of the responses to 6 questions (Questions 1a, 1b, 2a, 2b, 3a, 3b) on the Exercise and Sports Questionnaire (Appendix B). To calculate this index, the values assigned to the 3 frequency questions (Questions 1a, 2a, 3a) were as follows: None=1, <1day/wk=2, 1-2 days/wk=3, 3-4 days/wk=4, 5-6 days/wk=5, 7days/wk=6. Values assigned to the duration questions (Questions 1b, 2b, 3b) were as follows: None=1, <15 min=2, 16-30 min=3, 31-45 min=4, 46-60 min=5, >60 min=6. Values could range from 6 (None on all 6 questions) to 36 (7 days/wk on all 3 frequency questions and >60 min on all 3 duration questions).

d. Injury Data.

(1) To obtain injuries, Soldiers' medical records (DA Form 3444-6) were examined. Experienced medical records reviewers identified each visit to a medical care provider as either a visit for an injury or a visit for other medical care. For each injury visit, extracted information included the date of visit, type of visit (first or follow-up), activity associated with the injury, diagnosis, anatomical location of injury, disposition (final outcome of the visit), and days of limited duty (if any). These data were typically available on one of three forms: 1) Screening Note of Acute Medical Care (Department of the Army Form 5181-R), 2) the Chronology of Medical Care (Standard Form 600), or 3) Emergency Care and Treatment Form (Standard Form 558). Medical records screening procedures have been published previously (23).

(2) Based on past investigations, it was known that there would be injuries for which the medical care provider did not include an activity associated with the injury. A current e-mail address and phone number was obtained during the initial testing to facilitate follow-up interviews of Soldiers who sustain an injury. For any injury visit in the medical record that did not contain an associated activity, attempts were made to contact the Soldiers in person (at his/her work site), by phone, or by e-mail to obtain the activity associated with the injury. When Soldiers were contacted they were provided the date of the injury, the diagnosis, and the involved body part and asked how the injury had occurred.

e. Injury Case Definitions.

(1) We defined an injury case as a Soldier who sustained physical damage to the body (46) and sought medical care 1 or more times during the year following the initial testing. Using the diagnosis in the medical records, injuries were grouped by "type" for analysis. "Types" included any injury, overuse injury, traumatic injury, environmental injury, and lower extremity overuse injury. Injury types were determined by the nature of the energy exchange associated with the injury and by the specific diagnosis. Overuse injuries were presumably due to or related to long-term, repetitive energy exchanges resulting in cumulative microtrauma. Specific overuse diagnoses included musculoskeletal pain (not otherwise specified), stress fractures, stress reactions, tendonitis, bursitis, fasciitis, strains (muscle injury due to overuse), retropatellar pain syndrome, degenerative joint conditions, and shin splints. A traumatic injury was presumably due to sudden energy exchanges resulting in abrupt overload with tissue trauma. Specific diagnoses included pain (due to a traumatic event), sprains, dislocations, fractures, blisters, abrasions, lacerations, strains, and contusions. An environmental injury was presumably due to unusual exposure to weather, animals, or chemicals. Environmental injury diagnoses included heat-related injuries, cold-related injuries, burns, and animal bites. A lower extremity overuse injury was an overuse injury (as defined above) that also involved the lower extremities or lower back. "Any injury" included overuse and traumatic diagnoses as described above but excluded environmental injuries. These definitions are consistent with those used in past investigations (6, 10, 11, 13, 47-49).

(2) We examined two "levels" of injury that were assumed to involve different levels of severity. The first level included all visits to a health care provider for any type of injury regardless of whether or not limited duty was prescribed. The second level (a time-loss injury) included only those injuries that resulted in one or more days of limited duty (a profile).

(3) By combining injury types and levels we obtained 8 injury measures: any injury, overuse injury, traumatic injury, lower extremity overuse injury, any time-loss injury, time-loss overuse injury, time-loss traumatic injury, and time-loss lower extremity overuse injury.

(4) An encounter was defined as a visit in the medical record for any type of injury. Initial injury visits were first encounters resulting in a particular diagnosis at a particular anatomic location. Follow-up injury visits were encounters within a 6 month period resulting in the same diagnosis at the same anatomical location as the initial visit. If the period was greater than 6 months between encounters (initial or follow up), the encounter was considered a new injury even if the diagnosis and anatomical location were the same.

f. Deployment Data. Medical records did not contain deployment medical visits and the military units at Fort Bragg had often been deployed to Iraq. Information on Soldier deployments was obtained from the Defense Manpower Data Center (DMDC) and provided by the Army Medical Surveillance Activity. Extracted from the DMDC database were the start and end date of any deployments for Soldiers whose medical records had been screened. The number of days deployed within the medical records screening timeframe was calculated and designated the deployment time.

g. Data Analysis.

(1) Descriptive statistics were calculated for the mechanical performance measures, physical characteristics, physical fitness measures, and responses to the Exercise and Sports Questionnaire. BMI was calculated as body weight/stature^2 (31). Age was calculated as the number of years from the date of birth to the date of the initial testing. Frequencies were obtained for injury diagnoses, anatomical locations of the injuries, and activities associated with injury.

(2) To assess the "overall" physical activity, an Exercise, Sports and Mechanical Activity Index was calculated. This was the sum of the Exercise and Sports Index plus the Mechanical Frequency Index.

(3) Time at risk (1 year or fraction thereof) within the screening timeframe was calculated for each Soldier as:

365-deployment time

Injury incidence rates (injured Soldiers/100 person-years) were calculated as:

Σ Soldiers with $\geq$1 initial injury visits / (Σ total time at risk of all Soldiers) X 100

New injury rates (injuries/100 person-years) were calculated as:

Σ Initial injury visits / (Σ total time at risk for all Soldiers) X 100

Limited duty day rates (days/100 person-years) were calculated as:

Σ Limited duty days / (Σ total time at risk for all Soldiers) X 100

(4) By considering in the numerator only the specific diagnoses noted above in the injury case definitions, injury incidence rates and new injury rates were subcategorized into any injury, overuse injury, traumatic injury, lower extremity overuse injury, any time-loss injury, time-loss overuse injury, time-loss traumatic injury, and time-loss lower extremity overuse injury. Limited duty day rates were similarly subcategorized into any time-loss injury, time-loss overuse injury, time-loss traumatic injury, and time-loss lower extremity overuse injury.

(5) Cox regression (a survival analysis technique) was used to examine the association between the time to the first injury (any injury) and independent variables involving mechanical performance, physical characteristics, physical fitness, and physical activity. All continuous variables were converted to tertiles (3 approximately equal groups) based on the distribution of the variable. Both non-deployed and deployed Soldiers who were injured had their time censored at the date of the injury. Soldiers who were not deployed within the project timeframe and had no injury in the 1-year timeframe had their entire time considered. Soldiers who were deployed within the project timeframe and were not injured had their time censored on the first day of deployment and were not reentered into the analysis. Univariate Cox regression involved separate analysis with any injury as the dependent variable and each of the mechanical performance, physical characteristics, physical fitness, and physical activity measures as the independent variables. Multivariate analysis used a backward stepping procedure and included all independent variables with a p-value $\leq$0.25 in the univariate analysis (50).

(6) Cox regression was also to examine associations between the time to first mechanical work-related injury and the mechanical performance measures. It was thought that mechanical work-related injuries might be more highly associated with mechanical performance.

5. RESULTS. Because of difficulties in recruiting and retaining Soldiers only 135 volunteers participated in the initial testing out of the 160 required based on the statistical power analysis (84%). It was difficult to recruit Soldiers because small groups of mechanics were attached to the smaller airborne units and approval and scheduling for both briefings and testing had to be obtained from each unit commander. Furthermore, some Soldiers would volunteer for the testing but then declined to test on the day scheduled because of their work load or other assignments. Attempts were made to reschedule these Soldiers but the research team was on temporary duty at Ft Bragg and could not extend the schedule to meet the requirements of some of the Soldiers. Other factors further reduced the sample size. A number of Soldiers left Ft Bragg during the 1-year follow up period or their medical records could not be located for screening. Medical records were obtained on a total of 104 Soldiers of the 135 Soldiers who were initially tested (77%). Of the 31 men whose medical records could not be obtained, 15 had a permanent change of station (PCS), 11 left the service (ETS) and there were 5 Soldiers whose records could not be located for unknown reasons. Of the 104 Soldiers whose medical records were obtained, 35 were initially tested in Period 1 (March to April 2004) and 69 were initially tested in Period 2 (June 2004).

a. Descriptive Data.

(1) Mechanical Performance and Mechanical Frequency Measures.

(a) Table 5 shows the mean times for the mechanical performance tasks. There was 1 man who did not perform the starter replacement task and there were 3 men who could remove the starter but could not replace it. The 3 men who could not replace the starter all reported that they changed starters <monthly.

(b) The average±SD total time for the alternator replacement (excluding rest between removal and installation) was 16.1±7.8 minutes. The average±SD total time for the battery replacement (excluding rest) was 10.7±3.7 minutes. The average±SD total time for the starter replacement (excluding rest) was 16.7±10.6 minutes. The average±SD total time for the tire change (excluding rest) was 11.1±2.0 minutes.

Table 5. Mechanical Performance Measures

	Variable	**N**	**Mean (sec)**	**SD (sec)**
Alternator	Removal Time	104	229	90
	Rest Time Between Removal and Installation	104	287	118
	Installation Time	104	735	413
	Total Time with Rest	104	1251	550
	Total Time without Rest	104	964	468
Battery	Removal Time	104	186	79
	Rest Time Between Removal and Installation	104	207	83
	Installation Time	104	458	156
	Total Time with Rest	104	851	295
	Total Time without Rest	104	644	222
Starter	Removal Time	103	189	130
	Rest Time Between Removal and Installation	100	281	152
	Installation Time	100	815	428
	Total Time with Rest	100	1285	636
	Total Time without Rest	100	1004	513
Tire Change	Removal Time	104	187	44
	Rest Time Between Removal and Installation	104	216	47
	Installation Time	104	481	127
	Total Time with Rest	104	884	210
	Total Time without Rest	104	668	166

(c) Table 6 shows the self-reported frequency that the Soldiers performed the mechanical tasks. The one Soldier who did not perform the starter task is not included in the responses to the question on the frequency of starter replacement. Table 6 shows that the alternator and starter tasks were performed least often whereas the battery and tire change were performed more often. Only 17% of Soldiers (18/104) reported changing alternators at least weekly; only 13% of Soldiers (13/103) reported changing starters at least weekly. On the other hand, 47% of Soldiers (49/104) reporting changing batteries at least weekly; 48% of Soldiers (50/104) reported changing tires at least weekly.

Table 6. Self-Reported Frequency of Performance of Specific Mechanical Tasks

Response Category	Alternator		Battery		Starter		Tire	
	N	Proportion (%)	N	Proportion (%)	N	Proportion (%)	N	Proportion (%)
<Monthly	40	38.5	18	17.3	42	40.8	24	23.1
Monthly	17	16.3	16	15.4	26	25.2	8	7.7
2-3 times/month	29	27.9	21	20.2	22	21.4	22	21.2
1-2 times/wk	14	13.5	26	25.0	11	10.7	22	21.2
3-4 times/wk	4	3.8	14	13.5	2	1.9	15	14.4
Daily	0	0	9	8.7	0	0	13	12.5

(2) Physical Characteristics. Table 7 shows the ethnicity and rank of the Soldiers. There were 3 Soldiers whose medical records did not contain their ethnicities (listed as unknown in Table 7). Table 8 shows the physical characteristics of the subjects.

Table 7. Ethnicity and Rank of the Sample.

Ethnicity			Rank		
	N	Portion of Sample (%)		N	Proportion of Sample (%)
White	63	60.6	Private 1	1	1.0
Black	19	18.3	Private 2	12	11.5
Other	19	18.3	Private First Class	15	14.4
Unknown	3	2.9	Specialist	40	38.5
			Sergeant	22	21.2
			Staff Sergeant	5	4.8
			Sergeant First Class	9	8.7

Table 8. Physical Characteristics (n=104)

Variable	Mean	SD		Variable	Mean	SD
Age (yrs)	26.0	5.9		Body Fat (kg)	16.3	7.1
Height (cm)	176.0	6.6		Fat Free Mass (kg)	63.7	8.0
Weight (kg)	81.8	13.5		Lean Mass (kg)	60.8	7.7
Body Mass Index (kg/m^2)	26.4	4.0		Bone Mineral Density (gm/cm^2)	1.2147	0.1218
Body Fat (%)	19.7	6.3		Bone Mineral Mass (gm)	2930.0	450.7

(3) Physical Fitness Measures.

(a) APFT scores are shown in Table 9. APFT scores were obtained on 99 of the 104 Soldiers. Three of the 99 did not perform the run because of a medical profile. A recent APFT had not been taken by 2 Soldiers and the unit did not have APFT data for 3 Soldiers. The average±SD time from the date of the APFT to the date of the initial testing was 69±86 days.

Table 9. Army Physical Fitness Test Scores

Variable	N	Mean	SD
Push-Ups (reps)	99	63	14
Sit-Ups (reps)	99	65	10
Two-Mile Run (min)	96	14.7	1.3

(b) Table 10 shows the mean±SD values for the two highest trials on the isometric strength measures which were averaged to obtain the strength score. The correlations for the two trials are all ≥0.97 indicating excellent reliability. Table 11 shows the average values for the two dynamic strength measures and the 7 isometric strength measures.

Table 10. Two Highest Trials for the Isometric Muscle Strength Measures

Variable	N	Trial 1 (mean±SD)	Trial 2 (mean±SD)	Correlation
Hand Grip (lbs)	104	119±19	118±19	0.97
Elbow Extension (lbs)	104	28±9	28±9	0.99
Elbow Flexion (lbs)	104	30±7	30±7	0.98
Shoulder Flexion (lbs)	103	30±7	30±6	0.98
Back Extension (lbs)	104	182±33	183±33	0.98
Knee Extension (lbs)	102	255±65	255±66	0.98
Knee Flexion (lbs)	102	101±24	101±24	0.97

Table 11. Muscle Strength Measures

Variable	N	Mean	SD
Bench Press (lbs)	102	191	45
Incremental Dynamic Lift (lbs)	102	158	29
Hand Grip (lbs)	104	118	19
Elbow Extension (lbs)	104	28	9
Elbow Flexion (lbs)	104	30	7
Shoulder Flexion (lbs)	103	30	6
Back Extension (lbs)	104	183	33
Knee Extension (lbs)	102	255	65
Knee Flexion (lbs)	102	101	23

(4) Exercise and Sports Questionnaire. Tables 12 and 13 display the distribution of responses to the Exercise and Sports Questionnaire (Appendix B). For aerobic activity, 82% of the Soldiers reported exercising at least 3 days per week with 77% reporting exercising more than 30 minutes per session. For strengthening activities, 60% reported exercising at least 3 times per week with 66% reporting more than 30 minutes per session. Fewer reported playing sports. Only 13% reported playing sports at least 3 times per week but on days when sports were played, 65% reported that they played more than 30 minutes per session. With regard to self-reported overall physical activity (Table 13), 63% reported that they were much more active or somewhat more active than others of their age and sex. Only 9% reported that they were somewhat less active or much less active.

Table 12. Responses to the Frequency and Duration Questions on the Exercise and Sports Questionnaire

Category of Question	Response Category	Aerobic Activity		Strength Activity		Sports Activity	
		N	Proportion of Sample (%)	N	Proportion of Sample (%)	N	Proportion of Sample (%)
Frequency of Activity	None	0	0	1	1.0	26	25.0
	<1 day/wk	1	1.0	4	3.8	27	26.0
	1-2 days/wk	18	17.3	37	35.6	37	35.6
	3-4 days/wk	52	50.0	44	42.3	10	9.6
	5-6 days/wk	33	31.7	16	15.4	3	2.9
	7 days/wk	0	0	2	1.9	1	1.0
Duration of Activity	None	0	0	2	1.9	25	24.0
	<15 min	0	0	2	1.9	2	1.9
	16-30 min	24	23.1	31	29.8	9	8.7
	31-45 min	35	33.7	25	24.0	20	19.2
	46-60 min	37	35.6	36	34.6	22	21.2
	>60 min	8	7.7	8	7.7	26	25.0

Table 13. Responses to the Question on Overall Physical Activity on the Exercise and Sports Questionnaire

Response Category	N	Proportion of Sample (%)
Much More Active	20	19.2
Somewhat More Active	46	44.2
About the Same	29	27.9
Somewhat Less Active	8	7.7
Much Less Active	1	1.0

(5) Activity Indices. Table 14 provides descriptive data on the Exercise and Sports Index, the Mechanical Frequency Index and the Exercise, Sports, and Mechanical Activity Index.

Table 14. Descriptive Data on the Three Activity Indices

Index	N	Mean	SD
Exercise and Sports Index[a]	103	11.0	4.1
Mechanical Frequency Index[b]	104	22.5	4.4
Exercise, Sports, and Mechanical Activity Index[c]	103	33.5	6.7

[a]This was the arithmetic sum of the responses to 6 questions (Questions 1a, 1b, 2a, 2b, 3a, 3b) on the Exercise and Sports Questionnaire (Appendix B). Values assigned to the 3 frequency questions (Questions 1a, 2a, 3a) were None=1, <1day/wk=2, 1-2 days/wk=3, 3-4 days/wk=4, 5-6 days/wk=5, 7days/wk=6. Values assigned to the 3 duration questions (Questions 1b, 2b, 3b) were:: None=1, <15 min=2, 16-30 min=3, 31-45 min=4, 46-60 min=5, >60 min=6. Values could range from 6 to 36.
[b]When each of the 4 mechanical task was completed, Soldiers were asked to identify the typical frequency that they performed each task. (<Monthly, Monthly, 2-3 times/wk, 1-2 times/wk, 3-4 times/wk, Daily). The Mechanical Frequency Index was the sum of their 4 responses calculated by assigning numeric values to each response category as follows: <Monthly=1, Monthly=2, 2-3 times/wk=3, 1-2 times/wk=4, 3-4 times/wk=5, Daily=6. The index could range from 4 ("<Monthly" on all 4 tasks) to 24 ("Daily" on all 4 tasks).
[c]Sum of the Exercise and Sports Index and the Mechanical Frequency Index.

b. Injury Data.

(1) The 104 Soldiers had a total of 151 medical encounters (visits for injuries, initial and follow-up) and 92 new injuries (excluding follow-up visits). Within the 1-year timeframe, the total time at risk (non-deployed person-time) was 27,992 days (mean±SD=269±86 days). The total deployed time was 9,968 days (mean±SD=96±86 days).

(2) Table 15 shows the injury incidence rates. The traumatic injury incidence rates (all injuries and time-loss injuries) were higher than the overuse injury incidence rates (all injuries and time-loss injuries). Table 16 shows the new injury rates. The new traumatic injury rates (all injuries and time-loss injuries) were higher than the new overuse injury rates (all injuries and time-loss injuries). Total limited duty days and the limited duty day rates are shown in Table 17.

Table 15. Injury Incidence Rates

Measure	All Injuries		Time-Loss Injuries	
	Occurrences (n)	Injury Incidence Rate (injured Soldiers/ 100 person-years)	Occurrences (n)	Injury Incidence Rate (injured Soldiers/ 100 person-years)
Any Injury[a]	61	79.5	45	58.7
Overuse Injury	34	44.3	22	28.7
Traumatic Injury	38	49.6	27	35.2
Lower Extremity Overuse Injury	26	33.9	14	18.3

[a]Excludes 4 environmental injuries

Table 16. New Injury Rates

Measure	All Injuries		Time-Loss Injuries	
	Occurrences (n)	Injury Rate (injuries/100 person-years)	Occurrences (n)	Injury Rate (injuries/100 person-years)
Any Injury[a]	88	114.9	63	82.1
Overuse Injury	40	52.2	27	35.2
Traumatic Injury	48	62.3	36	46.9
Lower Extremity Overuse Injury	28	36.5	17	22.2

[a]Excludes 4 environmental injuries

Table 17. Limited Duty Days and Limited Duty Day Rates

Measure	Days(n)	Limited Duty Day Rate (days/100 person-year)
Any Time-Loss Injury[a]	1219	1591
Time-Loss Overuse Injury	612	799
Time-Loss Traumatic Injury	607	792
Time-Loss Lower Extremity Overuse Injury	433	565

[a]Excludes 4 environmental injuries

(3) Table 18 shows the distribution of new injuries by diagnoses. There were 40 overuse injuries totaling 43% of the total injuries. There were 48 traumatic injuries making up 52% of the total. There were 4 environmental injuries making up 4% of the total injuries.

Table 18. Injuries by Diagnoses

Injury Type	Diagnoses	Cases (n)	Proportion of All Injuries (%)
Overuse	Pain (NOS)[a]	24	26.2
	Strain (muscle injury associated with overuse)	7	7.6
	Retropatellar Pain Syndrome	3	3.3
	Tendinitis	2	2.2
	Stress Fractures/Stress Reactions	2	2.2
	Joint-Related Overuse	1	1.1
	Bursitis	1	1.1
Traumatic	Sprain (joint injury associated with trauma)	15	16.2
	Pain Associated with Trauma	12	13.0
	Contusion	6	6.5
	Strain (muscle injury due to trauma)	6	6.5
	Abrasion/laceration	6	6.5
	Fracture	3	3.3
Environmental	Insect or animal bite	3	3.3
	Heat injury	1	1.1

[a]NOS=Not Otherwise Specified

(4) Table 19 shows the distribution of injuries by anatomical location. There were 29 upper body injuries comprising 32% of the total injuries. There were 43 lower body injuries making up 47% of the total injuries. The locations with the highest number of injuries (in order of incidence) were the knee, lower back, ankle, and shoulder.

Table 19. Injuries by Anatomical Location

General Anatomical Location	Specific Anatomical Location	Cases (n)	Proportion of All Injuries (%)
Upper Body	Head	1	1.1
	Face	1	1.1
	Eyes	3	3.3
	Neck	1	1.1
	Chest	1	1.1
	Shoulder	8	8.7
	Elbow	2	2.2
	Lower Arm	1	1.1
	Wrist	5	5.4
	Hand	2	2.2
	Finger	3	3.3
	Upper Back	1	1.1
Lower Back	Lower Back	16	17.4
Lower Body	Pelvic Area	1	1.1
	Anterior Thigh	1	1.1
	Knee	17	18.5
	Calf	1	1.1
	Shin	2	2.2
	Ankle	15	16.3
	Foot	5	5.4
	Toe	1	1.1
Multiple Areas	Multiple Areas	1	1.1
Other	Other	1	1.1
Unknown	Unknown	2	2.2

(5) Activities associated with the injury are shown in Table 20. There were 75 injuries (82%) that had an associated training event listed in the medical records. An additional 6 injury activities were obtained by interview. Thus, an associated activity was obtained for 88% of the injuries (81/92). The category that accounted for the largest proportion of injuries was physical training. When sports and physical training were combined, these broad categories of activity were associated with 38% of all injuries for which an activity was obtained (32/81). Running was associated with 45% of the physical training injuries (9/20) and weight lifting with 20% (4/20). Landing problems were associated with 77% of airborne injuries (10/13), with a variety of actions associated with the remainder. Of the sports injuries, basketball and football were associated with 36% (4/11) and 18% (2/11) of the cases, respectively. The 9 mechanical work-related injuries were all traumatic in nature. They involved dropping objects on the body (n=3), striking objects (n=3), falls while working on vehicles (n=2) and a case where a Soldier bent over and experienced severe back pain while working in the motor pool (n=1).

Table 20. Activities Associated with Injury

Activity	Cases (n)	Proportion of All Injuries (n=92) (%)	Proportion of Injuries with Associated Activity (n=81) (%)
Physical Training	20	21.7	24.7
Airborne Activity	13	14.1	16.0
Sports	11	12.0	13.6
Mechanical Work	9	9.8	11.1
Chronic Conditions	8	8.7	9.9
Environmental	4	4.3	4.9
Road Marching	4	4.3	4.9
Garrison/Home Activity	3	3.3	3.7
Motor Vehicle Accidents	3	3.3	3.7
Field Training	2	2.2	2.5
Lifting	2	2.2	2.5
Fighting/horseplay	2	2.2	2.5
Unknown	11	12.0	0.0

Table 21. Associations Between Injuries and Mechanical Performance Variables

Task	Variable	Level Of Variable	Relative Risk (95% CI)[a]	p-value
Alternator	Removal Time	87-184 sec	1.00	Reference
		185-242 sec	1.01 (0.55-1.86)	0.99
		243-576 sec	0.95 (0.52-1.76)	0.88
	Rest Time	113-226 sec	1.00	Reference
		227-307 sec	1.12 (0.62-2.04)	0.71
		308-663 sec	0.84 (0.45-1.56)	0.57
	Installation Time	122-536 sec	1.00	Reference
		537-791 sec	1.33 (0.62-2.04)	0.36
		792-3600 sec	0.92 (0.49-1.71)	0.78
	Total Time with Rest	465-976 sec	1.00	Reference
		977-1362 sec	1.19 (0.66-2.17)	0.56
		1363-4420 sec	0.89 (0.47-1.67)	0.71
	Total Time without Rest	352-727 sec	1.00	Reference
		728-1061 sec	1.06 (0.58-1.94)	0.85
		1062-3987 sec	0.92 (0.50-1.71)	0.80
Battery	Removal Time	84-143 sec	1.00	Reference
		144-192 sec	0.97 (0.53-1.77)	0.92
		193-447 sec	0.82 (0.44-1.53)	0.54
	Rest Time	0-169 sec	1.00	Reference
		170-221 sec	1.08 (0.60-1.96)	0.79
		222-470 sec	0.80 (0.43-1.51)	0.50
	Installation Time	213-363 sec	1.00	Reference
		364-501 sec	1.06 (0.59-1.89)	0.85
		502-889 sec	0.70 (0.36-1.32)	0.26
	Total Time with Rest	418-679 sec	1.00	Reference
		680-896 sec	0.98 (0.54-1.76)	0.94
		897-1705 sec	0.70 (0.37-1.33)	0.28
	Total Time without Rest	317-505 sec	1.00	Reference
		506-696 sec	1.08 (0.60-1.93)	0.80
		697-1235 sec	0.70 (0.38-1.34)	0.28
Starter	Removal Time	58-123 sec	1.00	Reference
		124-179sec	0.84 (0.45-1.56)	0.58
		180-856 sec	0.90 (0.49-1.66)	0.73
	Rest Time	81-195 sec	1.00	Reference
		196-282 sec	0.72 (0.35-1.33)	0.30
		283-890 sec	0.72 (0.35-1.34)	0.30
	Installation Time	204-490 sec	1.00	Reference
		491-955 sec	0.98 (0.52-1.82)	0.94
		956-1800 sec	1.14 (0.59-2.21)	0.70
	Total Time with Rest	345-801 sec	1.00	Reference
		802-1492 sec	0.88 (0.48-1.63)	0.69
		1493-3476 sec	0.81 (0.42-1.57)	0.54
	Total Time without Rest	168-596 sec	1.00	Reference
		597-1148 sec	1.03 0.55-1.94)	0.93
		1149-2586 sec	1.26 (0.65-2.44)	0.50
Tire	Removal Time	116-165 sec	1.00	Reference
		166-190 sec	1.02(0.56-1.85)	0.96
		191-358 sec	0.76 (0.40-1.42)	0.38
	Rest Time	147-191 sec	1.00	Reference
		192-227 sec	0.99 (0.54-1.81)	0.97
		228-385 sec	0.76 (0.41-1.48)	0.44
	Installation Time	319-407 sec	1.00	Reference
		408-503 sec	0.97 (0.54-1.76)	0.92
		504-1133 sec	0.70 (0.37-1.34)	0.28
	Total Time with Rest	584-774 sec	1.00	Reference
		775-912 sec	0.81 (0.44-1.48)	0.49
		913-1818 sec	0.81 (0.43-1.51)	0.50
	Total Time without Rest	435-579 sec	1.00	Reference
		580-692 sec	0.82 (0.45-1.51)	0.53
		693-1455 sec	0.81 (0.43-1.50)	0.49

c. Associations between Mechanical Performance and Injuries.

(1) Table 21 shows the results of the univariate Cox regression examining associations between the mechanical performance measures and injury risk. There was little systematic association between time to perform the mechanical tasks and injury risk

(2) Table 22 shows the results of the univariate Cox regression examining associations between injury risk and the self-reported frequency of performing the more physically demanding tasks. In the columns labeled "Recoded Data", the responses were combined so that the last 3 categories (1-2 times/wk, 3-4 times/wk, Daily) were grouped into a single category (≥1 time/wk) for analysis. There was no systematic association between recoded self-reported task performance frequency and injury risk.

Table 22. Association between Injuries and Frequency of Mechanical Performance Tasks

Performance Task	Actual Data		Recoded Data			
	Frequency	N	Frequency	N	Relative Risk (95%CI)[a]	p-value
Alternator Change	<Monthly	40	<Monthly	40	1.00	Reference
	Monthly	17	Monthly	17	1.20 (0.56-2.57)	0.63
	2-3 times/month	29	2-3 times/month	29	1.66 (0.90-3.05)	0.10
	1-2 times/wk	14	≥1 time/wk	18	1.05 (0.48-2.31)	0.91
	3-4 times/wk	4				
	Daily	0				
Battery Change	<Monthly	18	<Monthly	18	1.00	Reference
	Monthly	16	Monthly	16	0.97 (0.38-2.45)	0.94
	2-3 times/month	21	2-3 times/month	21	0.92 (0.39-2.18)	0.86
	1-2 times/wk	26	≥1 time/wk	49	1.63 (0.80-3.32)	0.18
	3-4 times/wk	14				
	Daily	9				
Starter Change	<Monthly	42	<Monthly	42	1.00	Reference
	Monthly	26	Monthly	26	0.79 (0.41-1.52)	0.48
	2-3 times/month	22	2-3 times/month	22	0.91 (0.47-1.79)	0.79
	1-2 times/wk	11	≥1 time/wk	13	1.03 (0.46-2.29)	0.94
	3-4 times/wk	2				
	Daily	0				
Tire Change	<Monthly	24	<Monthly	24	1.00	Reference
	Monthly	8	Monthly	8	0.66 (0.19-2.30)	0.51
	2-3 times/month	22	2-3 times/month	22	1.60 (0.76-3.36)	0.22
	1-2 times/wk	22	≥1 time/wk	50	1.12 (0.59-2.12)	0.73
	3-4 times/wk	15				
	Daily	13				

[a]CI=Confidence Interval

d. Associations between Physical Characteristics, Fitness and Injuries.

(1) Table 23 shows the results of the univariate Cox regression examining the association between injuries, race, and rank. To increase statistical power, Private 1 and Private 2 were combined as were Staff Sergeant and Sergeant First Class. Associations are generally weak but lower-ranking enlisted Soldiers appear to be at higher risk than senior enlisted Soldiers.

Table 23. Association Between Injuries and Physical Characteristics

Variable	Level Of Variable	Relative Risk (95% CI)[a]	p-value
Race	White	1.00	------
	Black	1.12 (0.56-2.27)	0.75
	Other	1.35 (0.70-2.60)	0.37
Rank	Private 1-Private 2	1.46 (0.54-3.93)	0.45
	Private First Class	1.32 (0.46-3.79)	0.61
	Specialist	1.75 (0.75-4.08)	0.19
	Sergeant	1.51 (0.60-3.80)	0.38
	Staff Sergeant-Sergeant First Class	1.00	------

[a]CI=Confidence Interval

(2) Table 24 shows the results of the univariate Cox regression examining associations between the physical characteristics and injury risk. Higher body weight, higher BMI, more fat-free mass, and more lean mass were all associated with higher injury risk.

Table 24. Association Between Injuries and Physical Characteristics

Variable	Level Of Variable	Relative Risk (95% CI)[a]	p-value
Age	18.5-20.0 yrs	1.00	-----
	20.1-25.0 yrs	1.62 (0.50-5.25)	0.43
	25.1-30.0 yrs	1.36 (0.37-5.02)	0.65
	30.1-40.6 yrs	0.99 (0.28-3.53)	0.99
	159.3-172.8 cm	1.44 (0.79-2.62)	0.23
Height	179.9-179.0cm	0.96 (0.50-1.84)	0.90
	179.1-199.6cm	1.00	-----
	56.2-75.5 kg	1.00	------
Weight	75.6-88.5 kg	1.55 (0.82-2.93)	0.18
	88.6-118.0 kg	1.99 (1.04-3.80)	0.04
	17.7-24.4 kg/m²	1.00	-----
Body Mass Index	24.5-28.3 kg/m²	1.05 (0.82-2.93)	0.89
	28.4-38.4 kg/m²	2.02 (1.06-3.87)	0.03
	07.4-17.3 %	1.00	------
Body Fat (%)	17.4-22.8 %	1.16 (0.63-2.14)	0.65
	22.9-32.7 %	0.99 (0.53-1.85)	0.96
	04.9-13.3 kg	1.00	------
Body Fat Mass	13.4-19.3 kg	1.09 (0.59-2.03)	0.79
	19.4-36.2 kg	1.20 (0.65-2.24)	0.56
	46.6-59.6 kg	0.53 (0.28-1.03)	0.06
Fat Free Mass[b]	59.7-66.9 kg	0.71 (0.40-1.26)	0.24
	67.0-84.5 kg	1.00	------
	44.5-56.8 kg	0.53 (0.28-1.03)	0.06
Lean Mass[b]	56.9-64.0 kg	0.71 (0.40-1.26)	0.24
	64.1-81.0 kg	1.00	------
	2107-2694 gm	0.69 (0.37-1.28)	0.24
Bone Mass	2695-3042 gm	0.67 (0.37-1.23)	0.20
	3043-4177 gm	1.00	------
	0.960-1.140 gm/cm²	0.80 (0.44-1.46)	0.47
Bone Mineral Density	1.141-1.255 gm/cm²	0.59 (0.32-1.10)	0.10
	1.256-1.605 gm/cm²	1.00	------

[a]CI=Confidence Interval

[b]Despite independent assignment when the tertiles were developed, the same men are in similar tertiles of both lean body mass and fat free body mass. That is, men in Tertile 1 of lean mass are the same men in Tertile 1 of fat-free mass; men in Tertile 2 of lean mass are the same men in Tertile 2 of fat-free mass; etc.

(3) Table 25 shows the results of the univariate Cox regression examining associations between the APFT scores and injury risk. Soldiers performing fewer push-ups had lower injury risk compared to those performing more push-ups. A similar but much weaker trend is seen for sit-ups.

Table 25. Association Between Injuries and APFT Measures

Variable	Level Of Variable	Relative Risk (95% CI)[a]	p-value
Push-Ups	35-55 repetitions	0.57 (0.31-1.06)	0.07
	56-70 repetitions	0.51 (0.46-1.61)	0.04
	71-118 repetitions	1.00	------
Sit-Ups	40-59 repetitions	0.65 (0.32-1.31)	0.23
	60-70 repetitions	0.86 (0.46-1.61)	0.64
	71-93repetitions	1.00	------
Two-Mile Run	12.1-14.1 min	1.00	------
	14.2-15.2 min	0.94 (0.48-1.84)	0.87
	15.3-19.0 min	0.91 (0.47-1.75)	0.91

[a] CI=Confidence Interval

(4) Table 26 shows the results of the univariate Cox regression examining associations between the strength variables and injury risk. For the two dynamic strength measures, the bench press and IDL, lower levels of strength were associated with lower injury risk. For isometric strength measures the trends were similar for the back extensors, elbow flexors and hand grip. Knee flexor strength was inversely associated with injury risk; lower strength was associated with higher injury risk.

Table 26. Association Between Injuries and Strength Measures

Variable	Level Of Variable	Relative Risk (95% CI)[a]	p-value
Bench Press	110-165 lbs	0.61 (0.32-1.13)	0.12
	166-205 lbs	0.69 (0.37-1.26)	0.23
	206-315 lbs	1.00	------
Incremental Dynamic Lift	100-140 lbs	0.41 (0.22-.0.77)	<0.01
	141-160 lbs	0.67 (0.36-1.22)	0.19
	161-230 lbs	1.00	------
Hand Grip	080.0-107.6 lbs	0.77 (0.41-1.47)	0.43
	107.7-123.6 lbs	0.99 (0.55-1.79)	0.98
	123.7-176.0 lbs	1.00	------
Back Extension	116.5-168.0 lbs	0.59 (0.31-1.16)	0.10
	168.1-195.0 lbs	1.12 (0.62-2.01)	0.72
	195.1-275.0 lbs	1.00	------
Elbow Extension	15.6-23.2 lbs	0.83 (0.42-1.62)	0.58
	23.3-30.2 lbs	1.38 (0.77-2.49)	0.28
	30.3-68.6 lbs	1.00	-----
Elbow Flexion	13.1-27.5 lbs	0.74 (0.41-1.33)	0.32
	27.6-33.1 lbs	0.41 (0.22-0.79)	<0.01
	33.2-44.3 lbs	1.00	------
Shoulder Flexion	17.2-27.4 lbs	0.96 (0.51-1.79)	0.89
	27.5-32.4 lbs	0.95 (0.51-1.77)	0.86
	32.5-46.6 lbs	1.00	------
Knee Extension	118.7-232.3 lbs	0.88 (0.48-1.62)	0.69
	232.4-273.5 lbs	0.81 (0.43-1.52)	0.51
	273.6-496.7 lbs	1.00	------
Knee Flexion	53.8-90.8 lbs	1.75 (0.86-3.56)	0.12
	90.9-106.9 lbs	1.92 (1.00-3.69)	0.05
	107.0-169.5 lbs	1.00	------

[a] CI=Confidence Interval

(5) Table 27 shows the results of the univariate Cox regression examining associations between the responses to the Exercise and Sports Questionnaire and injury risk. A number of response categories were not used by the Soldiers and some response categories were used by few Soldiers. Response categories that had fewer than 5 Soldiers were not considered in the analysis. In general, there was no systematic association between responses to the questions and injury risk.

Table 27. Association Between Injuries and Exercise and Sports Questionnaire Variables

Variable	Level Of Variable	N	Relative Risk (95% CI)[a]	p-value
Days of Aerobic Activity	None	0	*	*
	<1 day/wk	1	*	*
	1-2 days/wk	18	1.06 (0.51-2.23)	0.87
	3-4 days/wk	52	0.91 (0.52-1.61)	0.75
	5-6 days/wk	33	1.00	Reference
	7 days/wk	0	*	*
Duration of Aerobic Activity	None	0	*	*
	<15 min/session	0	*	*
	16-30 min/session	24	0.90 (0.32-2.52)	0.84
	31-45 min/session	35	1.06 (0.40-2.83)	0.90
	46-60 min/session	37	0.79 (0.30-2.09)	0.63
	>60 min/session	8	1.00	Reference
Days of Strength Training	None	0	*	*
	<1 day/wk	5	1.55 (0.41-5.86)	0.52
	1-2 days/wk	37	1.46 (0.65-3.30)	0.36
	3-4 days/wk	44	1.51 (0.69-3.33)	0.30
	5-6 days/wk	16	1.00	Reference
	7 days/wk	2	*	*
Duration of Strength Training	None	2	*	*
	<15 min/session	2	*	*
	16-30 min/session	31	0.97 (0.38-2.46)	0.95
	31-45 min/session	25	0.57 (0.21-1.53)	0.26
	46-60 min/session	36	0.85 (0.34-2.10)	0.71
	>60 min/session	8	1.00	Reference
Days of Sports Activities	None	26	0.85 (0.34-2.12)	0.72
	<1 day/wk	27	0.98 (0.40-2.39)	0.97
	1-2 days/wk	37	1.28 (0.55-2.97)	0.57
	3-4 days/wk	10	1.00	Reference
	5-6 days/wk	3	*	*
	7 days/wk	1	*	*
Duration of Sports Activity	None	24	0.76 (0.37-1.58)	0.46
	<15 min/session	3	*	*
	16-30 min/session	9	0.45 (0.13-1.53)	0.20
	31-45 min/session	20	0.87 (0.40-1.88)	0.72
	46-60 min/session	22	1.39 (0.69-2.79)	0.85
	>60 min/session	26	1.00	Reference
Overall Physical Activity	Much More Active	20	1.00	Reference
	Somewhat More Active	46	1.40 (0.66-2.97)	0.38
	About the Same	29	1.80 (0.82-3.95)	0.15
	Somewhat Less Active	8	0.42 (0.09-1.94)	0.27
	Much Less Active	1	*	*

[a] CI=Confidence Interval

* Not considered in analysis

e. Associations between Activity Indices and Injuries. Table 28 shows the association between injuries and the 3 activity indices. There was a trend such that a higher Exercise, Sports and Mechanical Activity Index was associated with higher injury risk. A similar but much weaker trend was seen with the Mechanical Frequency Index.

Table 28. Association Between Injuries and Three Activity Indices

Index	Level Of Index	N	Relative Risk (95% CI)[a]	p-value
Exercise and Sports Index	10-19	31	1.00	Reference
	20-24	37	1.07 (0.57-2.00)	0.84
	25-32	36	1.08 (0.57-2.05)	0.81
Mechanical Frequency Index	4-9	35	1.00	Reference
	10-13	34	1.36 (0.72-2.59)	0.35
	14-20	34	1.39 (0.74-2.58)	0.31
Exercise, Sports and Mechanical Activity Index	14-30	33	1.00	Reference
	31-37	34	1.16 (0.60-2.27)	0.66
	38-48	36	1.53 (0.74-2.58)	0.18

[a] CI=Confidence Interval

f. Multivariate Analysis of Injuries and Other Variables.

(1) Multivariate analysis was performed on all variables with a p-value of at least 0.25 in univariate Cox regression. These variables included rank, BMI, bone mass, bone mineral density, fat-free mass, push-ups, sit-ups, bench press strength, IDL strength, back extensor strength, elbow flexor strength, knee flexor strength, Exercise Sports and Mechanical Frequency Index, duration of sports activity, and overall sports activity. For duration of sports activity, the response categories of "None" and "<15 min" were combined. For overall physical activity, the response categories of "much less active" and "somewhat less active" were combined. Despite the fact that height and weight reached the criteria for entry into the multivariate model, they were not included in the analysis since they were expected to covary with BMI as components of that measure.

(2) Table 29 shows the results of the backward stepping Cox regression. Higher BMI and lower knee flexion strength were independently associated with higher injury risk. Moderate levels of back extensor strength increased injury risk but moderate levels of elbow flexion strength, push-up performance or sit-up performance decreased injury risk. Lower bone mineral density was associated with reduced injury risk.

Table 29. Multivariate Analysis of Associations Between Injuries and Other Variables

Variable	Level Of Variable	Relative Risk (95% CI)[a]	p-value
BMI	17.7-24.4 kg/m^2	1.00	------
	24.5-28.3 kg/m^2	1.36 (0.54-3.40)	0.52
	28.4-38.4 kg/m^2	4.77 (1.83-12.44)	<0.01
Bone Mineral Density	0.960-1.140 gm/cm^2	0.52 (0.25-1.22)	0.10
	1.141-1.255 gm/cm^2	0.67 (0.30-1.47)	0.31
	1.256-1.605 gm/cm^2	1.00	------
Push-Ups	35-55 reps	0.82 (0.28-2.34)	0.71
	56-70 reps	0.27 (0.12-0.63)	<0.01
	71-118 reps	1.00	------
Sit-Ups	40-59 reps	0.75 (0.26-2.34)	0.61
	60-70 reps	0.50 (0.20-1.09)	0.09
	71-93 reps	1.00	------
Back Extension Strength	116.0-161.0 lbs	0.76 (0.33-1.77)	0.53
	161.1-195.0 lbs	2.26 (1.20-4.97)	0.04
	195.1-275.0 lbs	1.00	------
Elbow Flexion Strength	13.1-27.5 lbs	0.52 (0.24-1.12)	0.10
	27.6-33.1 lbs	0.13 (0.05-0.36)	<0.01
	33.2-44.3 lbs	1.00	------
Knee Flexion Strength	53.8-90.8 lbs	3.10 (1.18-8.14)	0.03
	90.9-106.9 lbs	3.13 (1.38-7.12)	<0.01
	107.0-169.5 lbs	1.00	------

[a] CI=Confidence Interval

g. Associations: Mechanical Performance and Mechanical Work Injuries. Table 30 shows the results of the univariate Cox regression examining associations between the mechanical performance measures and risk of a mechanical work-related injury. In general, there was little systematic association between time to perform the mechanical tasks and mechanical work-related injury. However, it is noteworthy that those who performed the slowest on the starter task tended to have the highest mechanical work-related injury risk.

Table 30. Associations between Mechanical Work Injuries and Mechanical Performance Variables

Task	Variable	Level Of Variable	Relative Risk (95% CI)[a]	p-value
Alternator	Removal Time	87-184 sec	1.00	--
		185-242 sec	1.03 (.21-5.13)	.97
		243-576 sec	1.00 (.20-4.96)	>.99
	Rest Time	113-226 sec	1.00	--
		227-307 sec	1.09 (.22-5.41)	.92
		308-663 sec	1.14 (.23-5.68)	.87
	Installation Time	122-536 sec	1.00	--
		537-791 sec	.80 (.13-4.82)	.81
		792-3600 sec	1.45 (.32-6.49)	.63
	Total Time with Rest	465-976 sec	1.00	--
		977-1362 sec	1.04 (.21-5.16)	.96
		1363-4420 sec	1.05 (.21-5.22)	.95
	Total Time without Rest	352-727 sec	1.00	--
		728-1061 sec	1.10 (.22-5.43)	.91
		1062-3987 sec	1.02 (.21-5.08)	.98
Battery	Removal Time	84-143 sec	1.00	--
		144-192 sec	.86 (.19-3.86)	.85
		193-447 sec	.56 (.10-3.06)	.50
	Rest Time	0-169 sec	1.00	--
		170-221 sec	.84 (.19-3.75)	.82
		222-470 sec	.56 (.10-3.06)	.50
	Installation Time	213-363 sec	1.00	--
		364-501 sec	1.24 (.31-5.00)	.76
		502-889 sec	.30 (.03-2.71)	.28
	Total Time with Rest	418-679 sec	1.00	--
		680-896 sec	.48 (.09-2.48)	.38
		897-1705 sec	.47 (.09-2.42)	.37
	Total Time without Rest	317-505 sec	1.00	--
		506-696 sec	.76 (.18-3.17)	.70
		697-1235 sec	.23 (.03-1.96)	.18
Starter	Removal Time	58-123 sec	1.00	--
		124-179sec	.33 (.03-3.15)	.33
		180-856 sec	1.74 (.41-7.28)	.45
	Rest Time	81-195 sec	1.00	--
		196-282 sec	1.53 (.26-9.19)	.64
		283-890 sec	2.16 (.40-11.82)	.37
	Installation Time	204-490 sec	1.00	--
		491-955 sec	.47 (.04-5.22)	.54
		956-1800 sec	3.5 (.71-17.47)	.13
	Total Time with Rest	345-801 sec	1.00	--
		802-1492 sec	.48 (.04-5.34)	.55
		1493-3476 sec	3.47 (.70-17.25)	.13
	Total Time without Rest	168-596 sec	1.00	--
		597-1148 sec	.50 (.05-5.55)	.58
		1149-2586 sec	3.59 (.72-17.83)	.12
Tire	Removal Time	116-165 sec	1.00	--
		166-190 sec	2.81 (.55-14.49)	.22
		191-358 sec	1.08 (.15-7.66)	.94
	Rest Time	147-191 sec	1.00	--
		192-227 sec	2.25 (.44-11.57)	.33
		228-385 sec	.98 (.14-6.94)	.98
	Installation Time	319-407 sec	1.00	--
		408-503 sec	.97 (.2-4.82)	.97
		504-1133 sec	1.15 (.23-5.71)	.87
	Total Time with Rest	584-774 sec	1.00	--
		775-912 sec	2.06 (.38-11.25)	.40
		913-1818 sec	1.65 (.28-9.88)	.59
	Total Time without Rest	435-579 sec	1.00	--
		580-692 sec	.95 (.19-4.69)	.95
		693-1455 sec	1.11 (.22-5.51)	.90

[a]CI=Confidence interval

6. DISCUSSION.

a. Injuries and Mechanical Performance.

(1) The major purpose of this study was to examine among Army wheel vehicle mechanics the association between injuries and occupational performance while controlling for other factors known to influence injury risk. However, the study found virtually no systematic relationships between overall injury risk and the various measures of mechanical performance. In univariate analysis, none of the mechanical performance measures reached the ad-hoc criterion for entry into the multivariate analysis ($p \leq 0.25$). The most parsimonious explanation for this finding is that mechanical task performance had little relationship with overall injury risk. Only 9 injuries (about 10% of all the injuries) were directly related to mechanical work and all of these were traumatic in nature. Attempts to relate these 9 injuries to task performance resulted in very small numbers of cases in each tertile. There was the suggestion of an association between mechanical work-related injuries and the starter task with higher risk among individuals in the slowest tertile. However, with the small sample size this relationship could not be supported statistically. The starter task was very physically demanding because it involved working in working under vehicle with arms extended over the body and, at times, supporting the 55 lb motor.

(2) It should also be remembered that we asked subjects to perform at a "normal" pace rather than at "maximal" pace and this instruction may have influenced the results. A "normal" pace was selected in order to duplicate performance on the actual task and because of safety concerns. If the subjects had been asked to remove and install the objects as fast as possible, that may have resulted in greater individual differences that might have more effectively discriminated among Soldiers in terms of their performance. Another evaluation method might also have been to ask skilled senior non-commissioned officers to subjectively rate Soldier performance as was done another study (51).

b. Injuries, Physical Characteristics, and Physical Fitness.

(1) Despite the lack of association between mechanical performance and injuries, some other risk factors were found to be related to injuries. Higher body weight and higher BMI increased the likelihood of injury in consonance with our previous study of wheel vehicle mechanics (23) and investigations of other MOS (17, 21, 22). In the multivariate analysis, BMI was the strongest single injury risk factor. In the civilian sports medicine literature most investigations examining associations between BMI and injuries have involved questionnaires (self-reported height, weight, and injuries) and the data is contradictory. Walter et al. (52) reported no association between body weight or BMI and running-related injuries (the latter defined as "severe enough to reduce the number of miles run, take medicine or see a health professional") but did not present their data. In one study, Macera et al. (53) found that low BMI was moderately associated with self-reported "muscle, joint or bone problems/injuries" attributed to running, while in another study Macera et al (54) found that higher BMI was shown to be a significant risk factor for self-reported (but physician diagnosed) orthopedic problems among men. Finally, Taunton et al. (55) reported that higher BMI (>26 kg/m^2) was protective; that is,

higher BMI was associated with less running-related pain for which the runner had seen a doctor or physical therapist. The occupational literature is somewhat more consistent in showing that high BMI is an injury risk factor. A case-control investigation of hospital workers showed that individuals with high BMI had greater risk of work-related injuries obtained from medical records (56). A longitudinal investigation of industrial and clerical workers demonstrated that physician-diagnosed upper extremity tendonitis was independently associated with BMI>30 when a number of other risk factors were considered (57). Higher BMI was also associated with work-related overexertion back injuries among female nurses (58) and with carpal tunnel syndrome diagnosed with nerve conduction studies in dental hygienists (59). There is some indication that individuals with higher BMIs have more serious ankle fractures than those with lower BMIs (60). On the other hand, BMI was not associated with self-reported back pain in Australian military helicopter pilots (61).

(2) Besides BMI, the present study also measured body composition allowing partitioning of the Soldier's body weight into fat mass, bone mass, and lean mass (the latter being fat-free mass minus bone mass). Higher body fat mass was only modestly associated with higher injury rates (risk ratio of highest fat mass tertile/lowest fat mass tertile=1.20) and body fat as a proportion of the body weight (%) shared no systematic association with injuries. The lack of association between body fat and injury was somewhat surprising in light of the relationship between BMI and injury discussed above. BMI and body fat have been shown to be highly correlated in past studies of civilian and military groups (29-31). In consonance with these past investigations, BMI and body fat mass shared a strong relationship in the present study demonstrating a correlation of 0.85 (Appendix C). A correlation of this magnitude indicates a shared variance (coefficient of determination or r^2) of 72% (62, 63); however, this leaves 28% of the variance unexplained. This unaccounted for variance may partly explain the difference between BMI and fat mass in terms of their respective associations with injuries. A similar dissociation between BMI and body fat in relation to injuries has been noted in infantry Soldiers (17).

(3) While body fat mass was only weakly related to injury risk, higher amounts of both fat-free mass and lean mass were associated with higher injury risk in a dose-response manner. This is contrary to intuition which might assume that individuals with more muscle mass might be less susceptible to injury (muscle mass makes up about 50% of fat-free mass (64, 65). Soldiers with more fat-free mass have higher aerobic capacities and higher muscle strength (66; also see Appendix D) and can perform physical tasks at a lower percentage of their maximal strength and endurance. Higher fat-free mass is also associated with greater maximal performance on occupationally-related military tasks like lifting heavy boxes (43, 66-68), carrying boxes (69), repetitive lifting (70), and digging (71). Soldiers with higher fat-free mass might be expected to be less susceptible to injury for these reasons.

(4) On the other hand, there may be situations where high levels of fat-free mass may not be advantageous. Fat-free mass makes up most of the body weight (78% on average in the present cohort). In the present study, physical activity was the training

event associated with the highest proportion of injuries with running alone accounting for 11% of all activities associated with injuries (9/81). In running, individuals with greater body weight put higher forces on the body each time the foot hits the ground. Ground impact forces during running average 2 to 3 times body weight during each foot strike (72-74). Individuals with more body weight (or more fat-free weight) will experience higher absolute ground reaction forces and the repetitive nature of these forces might eventually result in injury in susceptible individuals. The activity that was associated with the second highest proportion of injuries was airborne operations. Higher body weights tend to be associated with higher incidence of airborne injuries (75, 76), possibly because of faster parachute descent speeds that result in higher impact forces on landing (77).

(5) Besides the association of higher fat-free mass with injuries, there were several other surprising findings with regard to physical fitness. The general pattern in the strength measures was higher injury risk for the stronger Soldiers. These associations were most apparent for the dynamic strength measures (bench press and IDL) but were also present in the back extension measure. Isometric knee flexion did not show this pattern but rather the opposite, stronger Soldiers had lower injury risk. Previous studies in BCT (10, 78) and among infantry Soldiers (17) have shown no relationship between injuries and strength measured in a number of muscle groups.

(6) With regard to muscular endurance, lower performance on both push-ups and sit-ups was associated with lower injury rates. This contradicted much of the literature which showed that higher performance on push-ups and/or sit-ups was generally associated with lower injury rates in BCT (10, 13), AIT (15) and among infantry Soldiers (16, 17). Further, the present study found virtually no association between 2-mile run time and injuries despite the extensive literature showing this relationship in BCT (6, 8, 10, 79-84), AIT (15), and in a number of specific MOS (16, 17, 20-22).

(7) Because many of the associations between injuries and physical fitness contradicted much of the literature, other explanations were considered. One likely possibility for the contrary results was the small sample size. Because of problems with recruitment and retention, only about 65% (104/160) of the Soldiers required for the study based on statistical power analysis were actually tested and followed for injuries over the required 1-year period. The small number of Soldiers may have resulted in a less representative sample and all interpretations of the data should consider this.

(8) Another possibility was that Soldiers with higher levels of physical fitness (and those with more fat-free or lean mass) might be more physically active and thus more exposed to physical hazards. To explore this possibility, the Mechanical Frequency Index, the Exercise and Sports Index, and the Exercise, Sports and Mechanical Frequency Index were stratified on the body composition and fitness variables. Results are in Table 31. There were no significant differences on the 3 activity indices by various levels of fat mass or fat-free mass. Despite the lack of statistical significance, there is a trend suggesting increased fat-free mass is associated with increasing activity on all 3 indices. For fat mass, there is no trend for the Mechanical Frequency Index but on the Exercise

and Sports Index there is decreasing activity with increasing fat mass. On the strength variables, the relationships differ by muscle group. For the bench press, IDL and back extension (strength measures which showed increased injury risk with increased strength) the Mechanical Frequency Index demonstrated increased values with increased strength. For these same 3 strength measures, the pattern on the Exercise and Sports Index is inconsistent, with higher strength sometimes showing a lower index value (bench press and IDL). Other strength variables (hand grip, elbow extension, elbow flexion, knee extension, and knee flexion) showed inconsistent relationships on all indices. On the APFT variables, higher performance was systematically associated with higher values on both the Mechanical Frequency and Exercise and Sports Indices. On the whole, higher physical activity, as measured by these indices, was generally related to higher values for the physical characteristics or fitness measures that demonstrated the unusual relationships with injury (fat-free mass, bench press, IDL, back extension, push-ups, and sit-ups). However, there were some inconsistencies (bench press and IDL on the Exercise and Sports Index) and some strength and APFT variables that were not strongly associated with injury also showed higher physical activity at higher performance levels (hand grip, elbow extension, 2-mile run). In general, the inconsistencies suggest that physical activity, as measured by these indices, cannot assist in explaining the surprising findings with regard to the associations between body composition, fitness, and injuries in this study. It should also be considered that these indices are crude and do not cover all physical activity performed by Soldiers.

Table 31. Stratification of Physical Characteristics and Fitness Variables on Activity Indices

Variable Group	Variable	Level of Variable	Mechanical Frequency Index	Exercise and Sports Index	Exercise, Sports and Mechanical Frequency Index
Body Composition Variables	Fat-Free Mass	46.6-59.6 kg	10.4±4.3	21.9±4.5	32.4±6.7
		59.7-66.9 kg	11.0±3.8	22.5±3.9	33.5±6.5
		67.0-84.5 kg	11.7±4.3	23.1±4.7	34.6±7.0
		p-value[a]	0.22	0.27	0.18
	Fat Mass	4.9-13.3 kg	11.8±3.9	23.1±4.5	34.7±6.2
		13.4-19.3 kg	10.0±4.5	22.8±4.0	32.8±7.4
		19.4-36.2 kg	11.2±3.9	21.8±4.5	32.9±6.6
		p-value[a]	0.22	0.20	0.30
Strength Variables	Bench Press	110-165 lbs	9.8±4.3	20.8±4.1	30.6±6.6
		166-205 lbs	11.7±3.8	23.6±3.3	35.2±5.5
		206-315 lbs	11.8±4.2	23.3±4.9	35.1±7.0
		p-value[a]	0.04	0.01	<0.01
	Incremental Dynamic Lift	100-140 lbs	10.4±4.0	21.4±4.3	31.8±6.7
		141-160 lbs	11.7±4.3	24.1±3.5	35.1±5.7
		161-230 lbs	12.0±3.8	22.9±4.6	34.7±6.7
		p-value[a]	0.10	0.12	0.05
	Hand Grip	80.0-107.6 lbs	10.4±4.1	21.1±4.0	31.4±6.3
		107.7-123.6 lbs	11.5±4.3	23.2±4.1	34.7±6.7
		123.7-176.0 lbs	11.2±4.0	23.3±4.7	34.7±6.8
		p-value[a]	0.40	0.04	0.09
	Back Extension	116.5-168.0 lbs	10.4±4.3	22.0±4.6	32.3±7.1
		168.1-195.0 lbs	10.6±4.3	22.7±3.6	33.1±6.3
		195.1-275 lbs	12.1±3.8	22.9±4.8	34.9±6.7
		p-value[a]	0.08	0.40	0.11
	Elbow Extension	15.6-23.2 lbs	9.9±3.8	21.6±4.3	31.5±6.4
		23.3-30.2 lbs	11.1±4.3	22.9±4.4	33.7±7.1
		30.3-68.6 lbs	11.9±3.9	23.3±4.4	35.1±6.4
		p-value[a]	0.04	0.11	0.02
	Elbow Flexion	13.1-27.5 lbs	12.1±4.3	21.7±4.5	33.8±6.7
		27.6-33.1 lbs	9.6±4.4	22.6±3.7	32.2±6.9
		33.2-44.3 lbs	11.6±3.5	23.2±4.8	34.6±6.4
		p-value[a]	0.60	0.15	0.61
	Shoulder Flexion	17.2-27.4 lbs	11.7±4.1	22.4±4.1	34.1±6.2
		27.5-32.4 lbs	10.6±4.4	22.3±4.8	32.9±7.6
		32.5-46.6 lbs	10.9±4.2	22.9±4.3	33.7±6.4
		p-value[a]	0.41	0.67	0.81
	Knee Extension	118.7-232.3 lbs	10.9±4.2	22.3±4.2	33.2±6.4
		232.4-273.5 lbs	10.0±4.1	21.9±4.9	31.9±7.9
		273.6-496.7 lbs	11.9±4.1	23.5±3.9	35.2±5.7
		p-value[a]	0.30	0.25	0.21
	Knee Flexion	53.8-90.8 lbs	10.1±3.9	22.2±4.3	32.3±6.2
		90.9-106.9 lbs	11.7±3.9	22.8±5.0	34.5±7.4
		107.0-169.5 lbs	11.2±4.6	22.8±3.8	33.7±6.4
		p-value[a]	0.29	0.62	0.40
APFT Variables	Push-Up	35-55 reps	10.2±4.7	21.5±3.2	31.7±6.1
		56-70 reps	10.8±4.1	22.0±4.7	32.8±7.5
		71-118 reps	12.0±3.6	24.3±4.8	36.2±6.4
		p-value[a]	0.07	<0.01	<0.01
	Sit-Up	40-59 reps	10.0±4.7	22.1±4.3	32.1±7.8
		60-70 reps	11.0±4.0	22.4±4.2	33.4±6.0
		71-93 reps	12.1±3.8	23.7±4.6	35.6±6.5
		p-value[a]	0.07	0.15	0.05
	2-Mile Run	12.1-14.1 min	12.2±3.8	24.0±4.5	36.0±6.1
		14.2-15.2 min	10.4±3.9	22.1±4.3	32.5±6.6
		15.3-19.0 min	10.3±4.4	21.8±4.1	32.2±6.5
		p-value[a]	0.08	0.05	0.02

[a]Test for linear trend

c. Comparison of Past and Present Injury Data of Wheel Vehicle Mechanics.

(1) Table 32 compares the current study with our past investigation of wheel vehicle mechanics (23) in terms of injury incidence rates, new injury rates, and limited duty day rates. The injury incidence rates and new injury rates are remarkably similar despite the small sample size in the current study. It should be noted that 99 of the 104 Soldiers (95%) participated in both investigations. However, the time periods differed in which the data were collected. In the previous investigation (23), data were collected between March 2003 and February 2004; in the current study, data were collected between April 2004 and June 2005.

(2) Despite the close similarity in the injury incidence and new injury rates, Table 32 shows that the limited duty day rates were 13% to 40% lower in the present study compared to the past study (23). Investigations of light infantry units have shown that the average number of limited duty days can vary by more than a factor of 2 (16-18). Differences among providers in prescribing limited duty days, the differences in military and physical training intensity, and the tempo of operations are all possible explanations. The present data do suggest that the injuries experienced in the current study were less severe than those of our past study.

Table 32. Comparison of Injury Incidence Rates and Injury Rates in Two Studies

	Injury Type	Previous Investigation (23)	Current Investigation	Rate Difference (current-previous)	Proportional Difference (%)[a]
Injury Incidence Rates (injured Soldiers/100 person-years)	Any	72.0	79.5	7.5	10.4
	Overuse	41.3	44.3	3.0	7.3
	Traumatic	43.8	49.6	5.8	13.2
	Lower Extremity Overuse	34.9	33.9	-1.0	-2.9
	Any Time Loss	59.0	58.7	-0.3	-0.5
	Time-Loss Overuse	34.3	28.7	-5.6	-16.3
	Time-Loss Traumatic	34.6	35.2	0.6	1.7
	Time-Loss Lower Extremity Overuse	29.1	18.3	-10.8	-37.0
New Injury Rates (new injuries/100 person-years)	Any	124.1	114.9	-9.2	-8.0
	Overuse	60.9	52.2	-8.7	-14.2
	Traumatic	63.1	62.3	-0.8	-1.3
	Lower Extremity Overuse	30.7	36.5	5.8	18.9
	Any Time Loss	83.4	82.1	-1.3	1.6
	Time-Loss Overuse	40.2	35.2	-5.0	12.4
	Time-Loss Traumatic	43.2	46.9	3.7	8.9
	Time-Loss Lower Extremity Overuse	23.8	22.2	-1.6	-6.7
Limited Duty Day Rate (days/100 person-years)	Any Time-Loss	2076	1592	-485	-18.3
	Time-Loss Overuse	1164	799	-365	-31.6
	Time-Loss Traumatic	914	792	-122	-13.3
	Time-Loss Lower Extremity Overuse	945	565	-380	-40.0

[a]Calculated as (current-previous)/previous *100%

(3) Table 33 shows a comparison of injury anatomic locations in the current study and the previous one (23). In both investigations, the largest proportion of injuries involved the knee, ankle, and low back. The upper body area with the largest proportion of injuries in both investigations was the shoulder. Upper body, low back, and lower body were affected 34%, 19%, and 46%, respectively, in all cases in the past study; these values were 31%, 17%, and 47%, respectively, in the present study.

Table 33. Comparison of Injury Anatomical Location in Studies of Army Wheel Vehicle Mechanics

Body Area	Anatomical Location	Previous Investigation (23) Proportion of All Injuries (%)	Current Investigation Proportion of All Injuries (%)
Upper Body	Head	2.4	1.1
	Face	1.1	1.1
	Eyes	1.1	3.3
	Neck	4.1	1.1
	Chest	2.2	1.1
	Abdomen	0.9	0
	Shoulder	6.9	8.7
	Elbow	1.7	2.2
	Upper Arm	0.2	0
	Lower Arm	1.1	1.1
	Wrist	3.0	5.4
	Hand	3.0	2.2
	Finger	4.3	3.3
	Upper Back	1.9	1.1
Lower Back	Lower Back	18.8	17.4
Lower Body	Pelvic Area	0.9	1.1
	Hip	1.1	0
	Posterior Thigh	1.1	0
	Anterior Thigh	1.1	1.1
	Knee	15.7	18.5
	Calf	0.4	1.1
	Shin	4.1	2.2
	Ankle	12.1	16.3
	Foot	7.3	5.4
	Toe	2.4	1.1
Multiple	Multiple Areas	0.9	2.2
Unknown	Unknown	0.4	2.2

(4) Table 34 compares diagnoses in the past (23) and current investigations. The distribution of diagnoses in both studies is very similar. Pain (NOS), traumatic sprains, and pain associated with trauma rank as the three diagnoses with the largest proportion of cases.

Table 34 Distribution of Injuries by Diagnoses

Injury Type	Diagnoses	Previous Investigation (23) Proportion of All Injuries (%)	Current Investigation Proportion of All Injuries (%)
Overuse	Pain (NOS)[a]	22.0	26.2
	Strain (muscle injury due to overuse)	6.5	7.6
	Tendonitis	5.0	2.2
	Retropatellar Pain Syndrome	3.2	3.3
	Joint-Related Overuse	2.2	1.1
	Stress Fractures/Reactions	1.7	2.2
	Degenerative Joint Conditions	1.1	0
	Bursitis	1.1	1.1
	Fasciitis	1.1	0
	Shin Splints	0.9	0
	Other Overuse	2.6	0
Traumatic	Sprain (joint injury associated with trauma)	12.9	16.2
	Pain Associated with Trauma	8.8	13.0
	Contusion	7.1	6.5
	Strain (muscle injury due to trauma)	6.7	6.5
	Abrasion/laceration	4.7	6.5
	Fracture	3.7	3.3
	Other Traumatic Injuries	3.0	0
	Blister	1.5	0
	Dislocation	0.6	0
Environmental	Insect or animal bite	1.7	3.3
	Heat injury	0.2	1.1
	Contact dermatitis/burns	1.5	0

[a]NOS=Not Otherwise Specified

(5) Table 35 compares the current study with the past one in terms of activities associated with injury. In both studies, the 4 activities most often associated with injuries were physical training, mechanical work, sports and airborne activity. The frequency of injuries in association with airborne activities was about 1.7 times higher in the current investigation compared to the past. There were fewer injuries in association with road marching and garrison/home activities in the present study.

Table 35. Distribution of Activities Associated with Injury

Activity	Previous Investigation (23) Proportion of All Injuries (%)	Current Investigation Proportion of All Injuries (%)
Physical Training	20.0	21.7
Mechanical Work	10.6	9.8
Sports	10.1	12.0
Airborne Activity	8.2	14.1
Road Marching	6.7	4.3
Garrison/Home Activity	6.3	3.3
Chronic Conditions	5.6	8.7
Motor Vehicle Accidents	3.9	3.3
Field Training	3.9	2.2
Environmental	2.4	4.3
Fall from Military Vehicle	1.9	0
Lifting	1.9	2.2
Getting out of Bed	1.3	0
Ice	1.1	0
Fighting/Horseplay	0.9	2.2
Other	5.2	0
Unknown	10.1	12.0

d. Summary. The present investigation demonstrated little associations between mechanical performance tasks and injuries in Army wheel-vehicle mechanics. A weak association was demonstrated between the starter installation task and specific mechanical work-related injuries. Higher body weight or BMI was associated with higher injury rates in consonance with past investigations of mechanics and other military populations. Injuries were not related to body fat but higher levels of fat-free mass, generally lower strength, and lower performance on push-ups were associated with lower injury rates. Much of these latter findings do not agree with past investigations of similar or identical risk factors in other military populations. The data could not be explained by the self-reported frequency of mechanical activity or exercise and sport. The small number of Soldiers (n=104) could have resulted in an unrepresentative sample. Data on injury rates, anatomical locations of injuries, and activities associated with injury were very similar to a past investigation of Army mechanics.

Appendix A
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Appendix B.
Exercise and Sports Questionnaire

On the following questions, rate how often you exercised on average IN THE LAST YEAR:

1. AEROBIC EXERCISE

a. How many days per week did you perform aerobic exercise (running, cycling, swimming, etc) in the last year on average?

___ None
___ Less than 1 day/wk
___ 1-2 days/wk
___ 3-4 days/wk
___ 5-6 days/wk
___ 7 days/wk

b. On days you performed aerobic exercise (running, cycling, swimming, etc) in the last year, how long did you exercise on average?

___ None
___ Less than 15 min
___ 16-30 min
___ 31-45 min
___ 46-60 min
___ More than 60 min

STRENGTH TRAINING

a. How many days per week did you do exercise to improve your strength (free weights, universal, nautilus, push-ups, sit-ups, etc.) in the last year?

___ None
___ Less than 1 day/wk
___ 1-2 days/wk
___ 3-4 days/wk
___ 5-6 days/wk
___ 7 days/wk

b. On days that you performed exercise to improve your strength (free weights, universal, nautilus, push-ups, sit-ups, etc.) in the last year, how long did you exercise on average?

___ None
___ Less than 15 min
___ 16-30 min
___ 31-45 min
___ 46-60 min
___ More than 60 min

3. SPORTS ACTIVITY

a. How days per week did you participate in sports activities in the last year?

___ None
___ Less than 1
___ 1-2 days/wk
___ 3-4 days/wk
___ 5-6 days/wk
___ 7 days/wk

b. On days that you performed sports in the last year, how long did you exercise on average?

___ None
___ Less than 15 min
___ 16-30 min
___ 31-45 min
___ 46-60 min
___ More than 60 min

4. OVERALL PHYSICAL ACTIVITY. Overall, how would you rate yourself as to the amount of physical activity you perform, compared to others of your age and sex?

___ Much more active
___ Somewhat more active
___ About the same
___ Somewhat less active
___ Much less active

Appendix C.
Associations between Body Composition Variables and Body Mass Index

Table C1 shows associations between body composition, BMI and body weight in the present study. Generally, body weight is more strongly associated with lean mass and fat-free mass than is BMI. Both BMI and body weight are strongly associated with body fat mass.

Table C1. Associations Between Body Composition , Body Mass Index and Body Weight (values are correlation coefficients)

Body Composition Measure	Body Mass Index	Body Weight
Lean Mass (kg)	0.71	0.89
Fat-Free Mass (kg)	0.71	0.89
Body Fat (%)	0.74	0.67
Body Fat Mass (kg)	0.85	0.84

Multiple linear regression was used to examine the association between BMI and the body composition variables. Two models were examined. In the first model (three compartment), BMI was the dependent variable and fat mass, lean mass and bone mass were the independent variables. In the second model (two-compartment) BMI remained the dependent variable with fat mass and fat-free mass as the independent variables. A forward-stepwise procedure was used.

In both models the R value was 0.91 suggesting that 83% of the variance in BMI was accounted for by the 3 variables. In the three compartment model, body fat accounted for 72% of the variance, lean mass added 10% and bone mass added 1%. In the two-compartment model, fat mass accounted for 72% with fat-free mass adding 11%.

Table C2 shows the zero-order (Pearson product moment) correlation, partial correlations and part correlation between BMI and various body composition measures in three and two compartment models. The partial correlation is the relationship between 2 variables that remains after removing the variance due to the linear association with the other variables. Thus, in the three compartment model, the association between BMI and body fat is reduced only from 0.85 to 0.81 after removing the portion of the relationships due to bone and lean mass. This suggests that lean and bone mass share little of the variance in the association between fat mass and BMI. On the other hand, the association between lean mass and BMI is reduced from 0.71 to 0.36 suggesting that fat and bone mass account for a large proportion of the relationship. Results with bone mass are even more dramatic with a reduction in the relationship from 0.58 to 0.18 when the fat and bone variance is removed. Results with the two-compartment model are similar.

The part (or semipartial) correlation is also the correlation between a dependent (BMI) and independent (body composition) variable when the linear effects of the other variables are removed. It is related to the change in the r^2 when each new variable is added to the model.

Table C2. Correlations, Partial Correlations and Part Correlations Between Body Mass Index and Body Composition Variables

Model	Body Composition Variable	Zero-Order Correlation	Partial Correlation	Part Correlation
Three Compartment Body Composition Model	Fat Mass	0.85	0.81	0.57
	Lean Mass	0.71	0.36	0.16
	Bone Mass	0.58	0.18	0.08
Two Compartment Body Composition Model	Fat Mass	0.85	0.81	0.56
	Fat-Free Mass	0.71	0.62	0.32

Appendix D.
Associations between Lean Body Mass, Fat-Free Body Mass, and Strength

Table D1 shows strength values at various tertiles of lean body mass and fat-free body mass. Lean mass removes the bone mineral compartment from fat-free mass but bone mineral mass makes up only about 5% of the fat-free mass (mean±SD bone mass =2.9±0.5 kg; fat-free mass=63.7±8.0 kg). In the present study, the same men were in similar tertiles of lean body mass and fat free body mass despite independent assignment when the tertiles were developed. Thus, men in Tertile 1 of lean mass are the same men in Tertile 1 of fat-free mass; men in Tertile 2 of lean mass are the same men in Tertile 2 of fat-free mass; etc.

In all cases with the exception of shoulder flexion, strength systematically increased as lean body mass or fat-free body mass increases. The ratio of strength in highest to lowest lean body mass tertile ranges from 1.5 (bench press) to 1.2 (hand grip, elbow flexion, shoulder adduction, back extension).

Table D1. Association Strength at various levels of Lean Body Mass and Fat-Free Body Mass

Variable	Lean Body Mass Tertiles[a]	Fat-Free Mass Tertiles[a]	Mean±SD Strength (kg) at Lean Body Mass/Fat-Free Mass Tertile	p-value	Ratio (highest tertile/lowest tertile)
Bench Press	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	153±27 191±36 228±35	<0.01	1.49
Incremental Dynamic Lift	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	135±16 159±23 180±26	<0.01	1.33
Hand Grip	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	109±16 114±15 130±18	<0.01	1.19
Back Extension	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	167±30 179±27 201±32	<0.01	1.20
Elbow Extension	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	24±5 26±5 33±11	<0.01	1.38
Elbow Flexion	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	27±7 30±5 32±7	<0.01	1.19
Shoulder Horizontal Adduction	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	27±4 32±6 32±7	<0.01	1.19
Knee Extension	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	225±51 246±41 293±80	<0.01	1.30
Knee Flexion	44.5-56.8 kg 56.9-64.0 kg 64.1-81.0 kg	46.6-59.6 kg 59.7-66.9 kg 67.0-84.5 kg	91±16 100±22 113±27	<0.01	1.24

[a] The same men are in similar tertiles of both lean body mass and fat free body mass. That is, men in Tertile 1 of lean mass are the same men in Tertile 1 of fat-free mass; men in Tertile 2 of lean mass are the same men in Tertile 2 of fat-free mass; etc.

Table D2 shows the relationship between the various strength measures and lean mass and fat-free mass. The dynamic measures (bench press and IDL) show higher relationships than the static measures.

Table D2. Association Between Body Composition and Strength Measures (values are correlation coefficients)

Strength Measure	Lean Mass	Fat-Free Mass
Bench Press	0.71	0.72
Incremental Dynamic Lift	0.72	0.72
Hand Grip	0.55	0.56
Back Extension	0.42	0.43
Elbow Extension	0.54	0.54
Elbow Flexion	0.30	0.30
Shoulder Flexion	0.34	0.34
Knee Extension	0.52	0.52
Knee Flexion	0.50	0.49